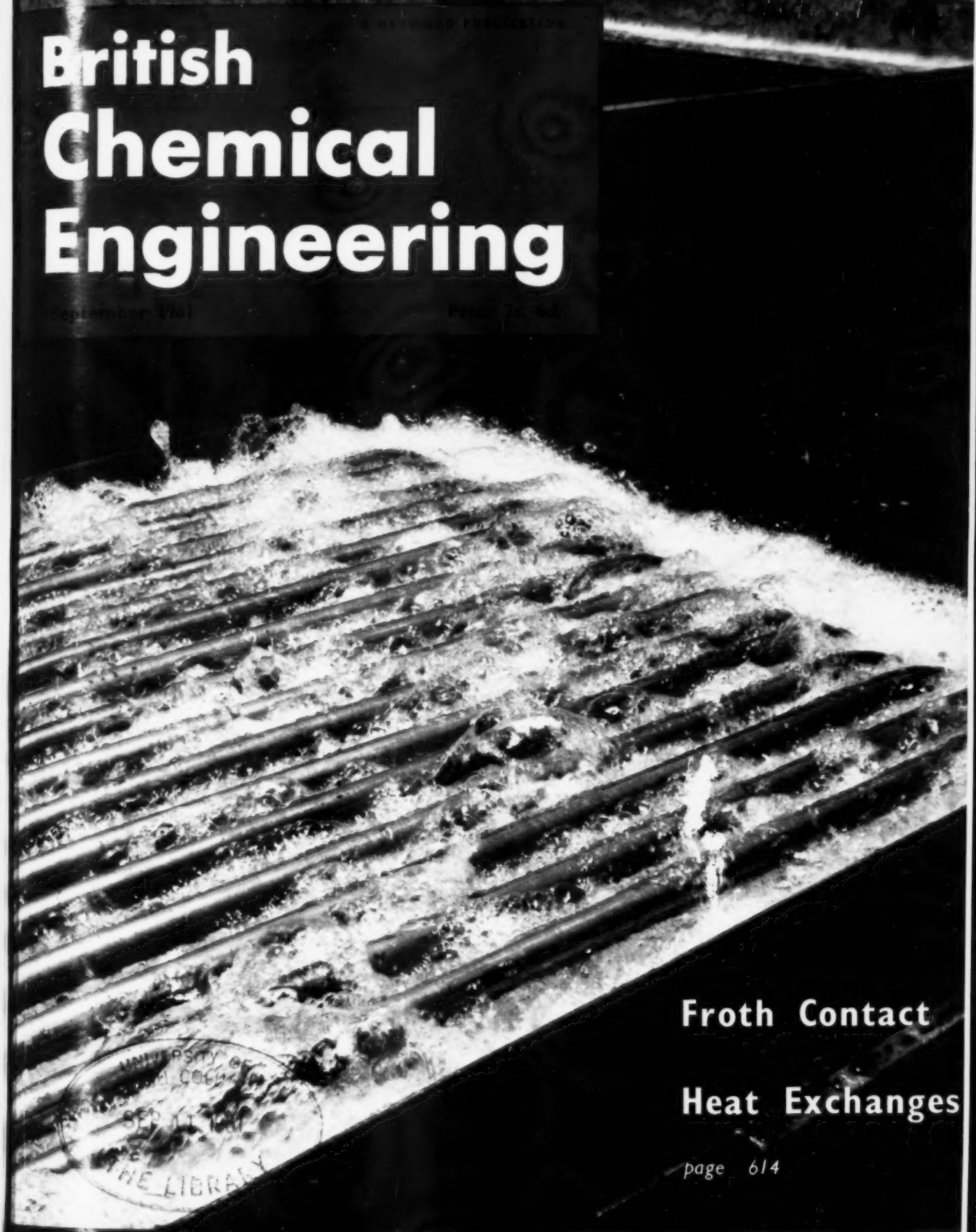
British Chemical Engineering



Froth Contact

Heat Exchanges

page 614

BURSTING DISCS

LOW AND MEDIUM PRESSURES

"Delanium" Graphite Bursting Discs are manufactured in two ranges, a LOW PRESSURE range covering pressures from 1–4 psig, and a MEDIUM PRESSURE range covering 5–400 psig, with orifice diameters of 2 in.–12 in. and 1 in.–12 in. respectively.

"Delanium" bursting disc assemblies are completely resistant to the corrosive attack of most acids, alkalis and solvents at temperatures up to 160°C. Manufactured from a high-quality graphite, the discs are precision ground to close tolerances and subjected to rigorous permeability and bursting-pressure tests to ensure accuracy of burst. The discs will withstand thousands of pressure applications at 75% of stated burst pressure without loss of accuracy. The design of the discs and vacuum supports assures ample relief opening on rupture for the rapid escape of excess pressures.

Replacement discs are quick and easy to install and for standard pressures are readily available from stock. Holders and vacuum supports costs are generally initial costs only and replacement discs are inexpensive.

RANGE OF DISCS AND PRESSURES	
Orifice Diameter	Bursting Pressure psig
1 in.	20-400
2 in.	4-200
3 in.	3-150
4 in.	2-100
6 in.	1-75
8 in.	1-40
10 in.	1-30
12 in.*	1-25

*** Larger diameter discs on application.**

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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Electrically Boosted Fuel-Oxidant Burner

A 3000°-6000°F heat source for chemical and metallurgical processes is being developed, from an invention by BELA KARLOVITZ of Combustion and Explosives Research Inc., Pittsburgh, Pa, by Arthur D. Little Inc. Known as the Combex-ADL burner, it boosts the energy of combustion of a fuel-oxidant mixtures by superimposing on the flame electrical energy from a low-current high-voltage A.c discharge.

The addition of electrical power equal to one-half the chemical combustion power at optimum air-fuel ratio increases the gas specific enthalpy from 1100 to 1600 Btu/lb. Enthalpies of 1900 Btu/lb can be obtained with fuel-rich flames, and still higher values are expected from increased electrical power.

Potential uses of the burner are for rapid high-temperature heating or as a localised heat source above 3000°F: for instance, impingement heating for cutting, welding, spalling, scarfing and drilling. If refractory materials for suitably high temperatures can be economically used, the boosted burner can supply both radiant heat, as in open hearth steel furnaces, and indirect heating. Other possible applications include fluidized bed processes, submerged combustion techniques, reduction of aluminium, boron and magnesium oxides, the preparation of acetylene from natural gas, and glass melting.

Operating costs depend on the fuel, oxidant and electric power used and the temperatures required. Any commercially available fuel—natural gas, fuel oil, powdered coal or hydrogen—can be used with a range of oxidisers from air or oxygen to fluorine or exotic mixtures. By varying feed rates, the burner is expected to provide a reducing, neutral, or oxidising atmosphere.

Whereas the high-current low-voltage system of the electric arc produces a very high temperature in a narrow column of the arc, the low current and high voltage of the new burner produce a discharge uniformly distributed through a much larger volume of the flame. So far, a 60 cycle supply has been used at discharge potentials up to 2000 volts and currents to 12 amperes: conditions readily available for industrial applications.

Crystallizer Design

SOME of the problems associated with the selection, design, scale-up and operation of industrial crystallizers have been discussed recently,* in relation particularly to the modern suspension units.

The performance of a crystallizer is affected by a large number of variables. Amongst these the following are most common:

1. solubility and phase relationships
2. heats of solution and heat capacities
3. solution viscosities and vapour pressures
4. suspension densities
5. crystal settling rates in saturated solution
6. crystal growth rates.

All these data must be available before a successful design can be commenced. Fortunately most of them can be obtained relatively easily either from the literature or by simple laboratory trials.

There are, however, two other factors that can have a profound influence on the crystallization process, viz., the effects of supersaturation on the nucleation rate and growth rate on the crystal habit. In fact these variables are usually so difficult to measure or control that the problem is best resolved by determining, in a pilot crystallizer, the degree of restraint required to achieve the desired product in terms of:

(*a*) the intensity of agitation
(*b*) the seed rate dosage
or (*c*) the size of the fines separator.

As far as agitation is concerned, it is suggested that the draft-tube with an internal impeller gives the best results at minimum cost. Artificial seeding is used to control both the supersaturation and the crystal growth rate. The object here is to provide sufficient crystal surface to maintain the working supersaturation at a level where spontaneous nucleation is negligible compared with the seed requirement. The installation of a suitable fines trap is considered to be of paramount importance.

Perhaps the greatest difficulty in scaling-up a crystallizer arises from the fact that scale-up itself is a dominant variable. The optimum operating conditions for large and small equipment do not necessarily coincide, and it therefore becomes necessary to design for flexibility.

*W. C. SAEMAN in a paper "Crystallization Design Fundamentals" presented on March 21-30 to the 139th National Meeting of the American Chemical Society held at St. Louis.

Electrically-Heated Fluid Bed

HOW many forgotten inventions are likely to be rediscovered and applied commercially in the future? This question is prompted by a recent investigation* of a type of fluid bed reactor first patented by F. WINKLER of I.G. Farbenindustrie in 1928. In this reactor, energy is fed directly to the reactant system by passing an electric current between electrodes immersed in a bed of conductive fluidized particles, coke being the best example.

Such a reactor has many potential applications in chemical reaction technology. For example, those requiring considerable supplies of energy, especially at high temperature levels, say above 1000°C, which prefer rapid heating: reactions which, through thermodynamic or kinetic effects, are favoured by higher temperatures. Examples of such reactions are the formation of CS_2 from petroleum coke and hydrogen-sulphide, CS_2 from petroleum coke and sulphur, HCN from ammonia and hydrocarbons, and HCN from ammonia and coke.

Results obtained from recent laboratory-scale experiments, with graphite, show that at temperatures around 1400°C for the first of these reactions 55% H_2S and CS_2 efficiencies of 92-94 per cent were obtained with production rates of

something like 15 lbs-20 lbs CS_2/cu ft coke/h. In the case of the second reaction a 70 per cent conversion was obtained at 1100°C and the production rates were 20 lbs CS_2/cu ft coke/h. In both these processes graphite was found to be the most useful material of construction for the reaction zone. Similar useful results were obtained for the other two reactions, thus, the yield of HCN from ammonia and hydrocarbon gases was 85-90 per cent. Other reactions, where the electro-fluid reactor may be distinctly successful, are the direct chlorinations of refractory oxides in the presence of coke, H_2O-C reactions, cracking and the preparation of metal sulphides from metal oxides and sulphur, a further use is as a pre-heater for chemical reactions, for example, preheating the recycle gas stream in iron reduction processes.

Many advantages are to be seen, for example, most conventional fluid-bed reactors are heated by combustion fuel, often in a chamber separate from the reaction zone; with such a system the heat-transfer from burning fuel has two characteristics which reduce its efficiency at high temperatures: (1) the heat transfer rate depends on the temperature difference between flue gas and fluid bed. This is a serious limitation at temperatures above 1200°C, because a small fraction only of the sensible heat in the flue gas can be transferred to the bed. The remainder has to be recovered by waste-heat boiler or by other means if reasonably efficient fuel utilisation is to be achieved. The direct supply of heat to the reactor system, characteristic of the electro-fluid reactor, avoids these serious shortcomings.

H. S. JOHNSON discusses this process, its potentialities and some of the laboratory reactor design features. For safe electrical operation, he advises that the coke particles must be in motion in the vicinity of the electrodes. Good dispersion of the fluidizing gas is essential and on the laboratory-scale a porous disc diffuser proved useful. An alternative, when this is not practicable, is the multi-jet disperser or bubble cap; suitable materials of construction are porous carbon, graphite, and "Vycor."

*"Reactions in a Fluidized Coke Bed with Self-Resistive Heating," Can.J.Ch.E. 1961, 39, (3), 145-147.

Controlling Air Pollution

DUST emission from cement works is one of the nuisances reviewed at length in the 97th Annual Report on Alkali, & C. Works, 1960. Most of the cement produced in Britain is made by the wet-slurry long-kiln technique in which a slurry of chalk or limestone and clay containing about 40 per cent of water is fed continuously into the upper end of a slowly-rotating inclined cylindrical kiln. Pulverised coal or fuel oil is burned at the lower end. The hot gases passing along the kiln to the feed end pick up dust; some of this is removed by a thick curtain of chains, but the gases are still appreciably dust-laden on leaving the kiln.

There are two main difficulties in treating the waste gases —firstly, their large volume—around 200,000 cu ft per ton of cement clinker, secondly, and more important, their high moisture content, about 40 per cent. Unless the gases are kept above dewpoint, condensation can occur giving rise to corrosion and electrical failure of electrical dust precipitators. In a new kiln, it is possible to locate chimney, electrical dust precipitator and kiln close together so that the gases are kept above the dewpoint. In already existing kilns and chimneys, however, long flues are often unavoidable.

Electrical precipitators used in such circumstances need constant attention and maintenance. For this reason, electrical precipitation is not usually demanded by the Inspectorate at older works, except in cases of major public complaint. High duty cyclone arrestors, although they have a lower dust arrestment efficiency, are reasonably constant in operation and need far less maintenance. Full scale trials with cyclones over long periods suggest that they will give adequate dust arrestment for medium sized works and certainly for small works. There are still some older works which rely only on an internal chain system for reducing dust emission, but these are being progressively equipped with more effective installations.

Semi-dry processes of cement making, which may soon challenge the supremacy of the wet-slurry method, are more easily dealt with by electrical precipitator as the condensation hazard is much smaller. Moreover, most of these are new installations.

Another air pollution hazard reviewed is the emission of acid mist from sulphuric acid works using the contact process —now the dominant method. This is becoming increasingly important because of the greatly increased scale of acid production units.

The mist is almost unaffected by passage through standard absorption plant in which sulphuric acid is readily soluble. The mechanism of mist formation and its removal is still obscure. A filtration mist arrestor which is giving satisfactory results on one production unit has proved ineffective on a second unit on the same site using the same raw materials. Where the raw material is anhydrite, mist formation seems inevitable and the Inspectorate propose to require that means to deal with it shall be provided in the design stage. Where brimstone is the raw material, there may or may not be a mist problem and here the Inspectorate require that space shall be left for the intercalation of mist arrestment plant should it prove to be necessary. Electrical precipitation is a solution to the problem, but an expensive one.

Pilot scale and full scale works trials of other techniques for dealing with the mist problem are in hand. Glass wool filters have been used with appreciable success.

Australian Chemical Engineering Research

THE direct hydrogenation of brown coal, fluidization for mineral processing, solids processing, and studies of mass transfer and reaction rate kinetics were among the main topics investigated by the Chemical Engineering Section of the Australian CSIRO during 1959-1960.*

For producing a methane-rich gas and simultaneously, a high degree of gasification, a new experimental plant for the hydrogenation of brown coal is being commissioned. It has a 20 ft deep fluidized bed reactor, baffled to give essentially countercurrent flow of the coal and hydrogenating gas.

In studies of carbon gasification reactions, it has been found that at pressures up to 40 atm and temperatures in the range 790-870°C, the reaction between carbon and carbon dioxide shows features analogous to those of the carbon-steam system. The retarding effect of carbon monoxide is lessened as the carbon dioxide partial pressure is increased. The reverse reaction may be more complex. There is now considerable experimental evidence that the reactivity of carbons is a function of the amounts of chemically combined hydrogen and oxygen present, and is inversely related to the hydrogen/oxygen ratio.

Mineral processing studies include the reduction of iron ore with hydrogen in a fluidized bed reactor, focusing particularly on the factors which cause agglomeration. Other investigations concern new and more efficient methods of recovering tin from low grade pyrrhotite ores found in Tasmania, and an economic appraisal of the Gaskin-Ringwood process for producing rutile from ilmenite.

For particle sizing in the sub-sieve range, a highly efficient batch elutriator, utilising a small hydraulic cyclone with a sample container connected to the apex opening, has been developed. Precise separations of quartz powders have been

GAPMETER DESIGN CRITERIA

A specification for Rate-of-Flow meters, which in a period of less than three years, has resulted in the Gapmeter being widely adopted in the Chemical, Process and Engineering industries

SAFETY

The Gapmeter glass tube is made from Pyrex glass, carefully annealed. It is not subject to any assembly or pipework stresses. No glass tubes larger than ¾ in. I.D. are used. The Gapmeter glass tube floats on two 'o' seals and is completely enclosed by a Perspex cover. A Test Certificate can be issued.

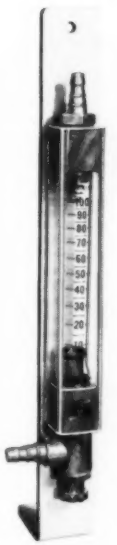
COMPACT SIZE

Gapmeters have 4 in. scales except Size 2 with 1½ in. scale; all designed for easy reading to 0.5% F.S.D. Back Plate dimensions range from Size 2 (⅛ in. pipe) 1¼ in. x 4¼ in. and Size 1 (¼ in. pipe) 1¼ in. x 7¼ in., to Size 10 (¾ in. pipe) 1½ in. x 7¾ in. and Extension Pocket Size 25 (1 in. pipe) 2 in. x 17 in.

LOW PRICE

The Gapmeter is made up of the minimum number of components; and all are designed for quantity production from bar stock. Components are interchangeable. No serial numbering of floats or tubes is necessary. The Gapmeter may be dismantled and re-assembled very easily. Tube mounting blocks are identical.

LOW PRICE, INTERCHANGEABILITY AND COMPACTNESS LEAD TO NEW GAPMETER APPLICATIONS



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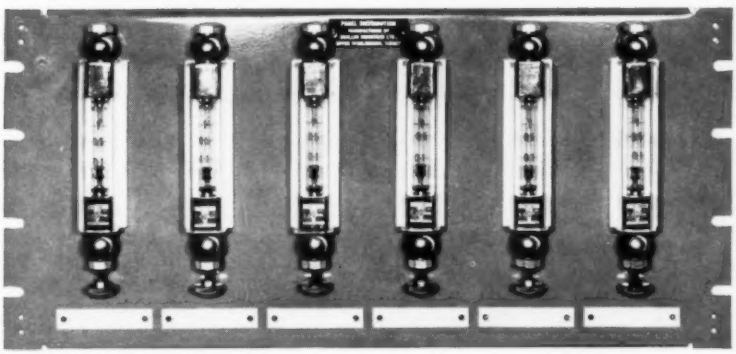
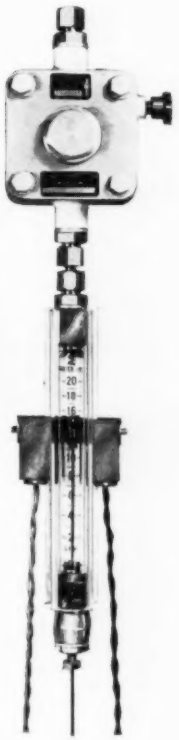


Photograph by courtesy of Drallim Industries Ltd.



Gapmeters are being employed to advantage in a widening field of industrial activities. The special bench-mounting Gapmeter shown on the left is used in the welding of plastics with hot gases. Above is a panel for indicating the flow of dry air through G.P.O. cables. On the right a Flostat Minor adjustable flow controller is used in line with a Gapmeter fitted with the Flo-scan Flow Alarm to control cooling water for transmitter valves.

THE GAPMETER RANGE

The small Gapmeters, with glass metering tubes, are for pipe sizes; ⅛ in., ¼ in. and ⅜ in. with Nozzle, Straight Union or Banjo fittings—interchangeable for Front or Back of Panel connection. Prices from £2. 15. 0d. The large, extension pocket Gapmeters, are for pipe sizes; ½ in., ¾ in. and 1 in. with Nozzle, Compression Union or Banjo fittings. Prices from £12. Main orifice and "Shunt" Gapmeter assemblies are made for pipe sizes 1½ in. and above.

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obtained at selected size intervals between 40 and 8 microns, and the range can probably be extended.

For investigating the dynamic behaviour of ball-mill grinding circuits, and possible methods of automatic control, a small-scale grinding circuit is under construction.

To provide accurate measurements of fundamental mixing characteristics of non-Newtonian materials such as plastics, doughs and rubbers, a laboratory-scale extruder-mixer has been built. New methods for assessing the efficiency of mixing of thick slurries have been successfully tried out, and large scale equipment is now under construction for more detailed experiments.

A prototype trailer-mounted hydraulic cyclone machine for the continuous dissolution of gypsum in irrigation water has made possible dissolution efficiencies of approximately 80 per cent with water flow rates up to 2 ft ^{3}/sec with gypsum concentrations up to 20 milliequivalents per litre. A simple version, using a 44 gallon drum as the cyclone, has been designed for construction by farmers.

In studies of the fluid dynamics of two-phase liquid systems in the glass-sided flow channel, optical and photographic methods for measuring very low liquid velocities have been investigated, but efforts are now concentrated on developing a liquid differential pressure gauge sensitive to differential pressures of the order of 10^{43} inch water gauge, which could be used with micro-pitot tubes.

Among projects undertaken by the process equipment laboratory was a design study to evaluate the cost of recovering formic acid from dilute aqueous solutions produced in a new continuous wool-dyeing process being developed by the Division of Protein Chemistry.

*Chemical Research Laboratories CSIRO, Annual Report 1959-1960.

Handling Highly Flammable Liquids

ENSURING the safety of personnel and plant when handling dangerous fluids demands in the first place a recognition of what the hazards are. Some of the lesser-appreciated hazards in the handling of highly flammable fluids have been highlighted recently in a paper by MR. J. HOWLETT, Director of the Distillers Company Ltd., read before the National Industrial Safety Conference at Scarborough in May.

Among possible sources of ignition, sparking from static electricity can arise from a number of sources—transmission belting on pulleys; paint spray guns; agitation; vehicles and persons in motion; flow of liquids, particularly at the point of issue from the pipe outfall; and grinding operations. Liquids with resistivities higher than 10^{13} ohm/cm could build up "static" to dangerous levels, and earthing of pipes with electrical continuity to tanks and vessels is then essential. Wet steam from leaking joints could also cause a discharge hazard. Motion of the body can also cause electrification, and charges of 600 volts have been found in female clerical staff wearing nylon underwear and leather shoes after walking briskly for only 25 yards. Conducting footwear should be the rule for use in dangerous locations. On road tankers fitted with up to 12 tyres, charges of 300 volts have been observed, which emphasises the need for earthing before any operations commence.

Another ignition source is frictional sparks, about which there is still much to be learnt. Dangerous friction can occur between metal and metal, and between rock and metal. The use of reduced-sparking tools instead of steel tools is not generally justified, except as an added insurance in tanks and enclosed spaces being cleaned. Even so, wooden scrapers are to be preferred. It is possibly more important to ensure that precautions are taken against tools being dropped, especially on to concrete flooring. If for any reason chipping of concrete or similar operations are essential, the surface should be kept thoroughly wetted or a CO_2 atmosphere should be applied at the point of impact. Light alloy tools should never be used in dangerous atmospheres where there is any possibility of the tool falling and striking steel, possibly giving rise to a highly incendive flash.

Preventive actions cover tankage layout, and isolation from possible sources of ignition; adequate earthing—bearing in mind that some liquids with flash points higher than those normally classed as highly flammable may be more prone to static charge buildup; provision of flame arrestors in breather lines, and their regular inspection; fitting tanks with cooling sprays and foam applicators; and inerting with gas to keep oxygen content below 10 per cent.

In process operations, precautions include the detailed instruction of operators, siting the process on open structures, remote control, small process tanks and avoidance of spillage, fitting process vessels with relief valves and bursting discs, flame arrestors or packed towers in process lines, and operation of processes, where possible, in the "safe" areas of concentration of flammable fluids. In the case of acetylene, which is liable to self-detonation in some circumstances, nitrogen dilution can be effective within limits—but the percentage of nitrogen required increases rapidly with pressure, from 10-12 per cent at 3 atm to over 50 per cent at 6 atm. Another method of protection, the Graviner explosion suppression system, is of very wide application and worth considering inprocess design involving inherently dangerous conditions.

Analogue Simulation of a Radial Flow Moving Boundary Problem

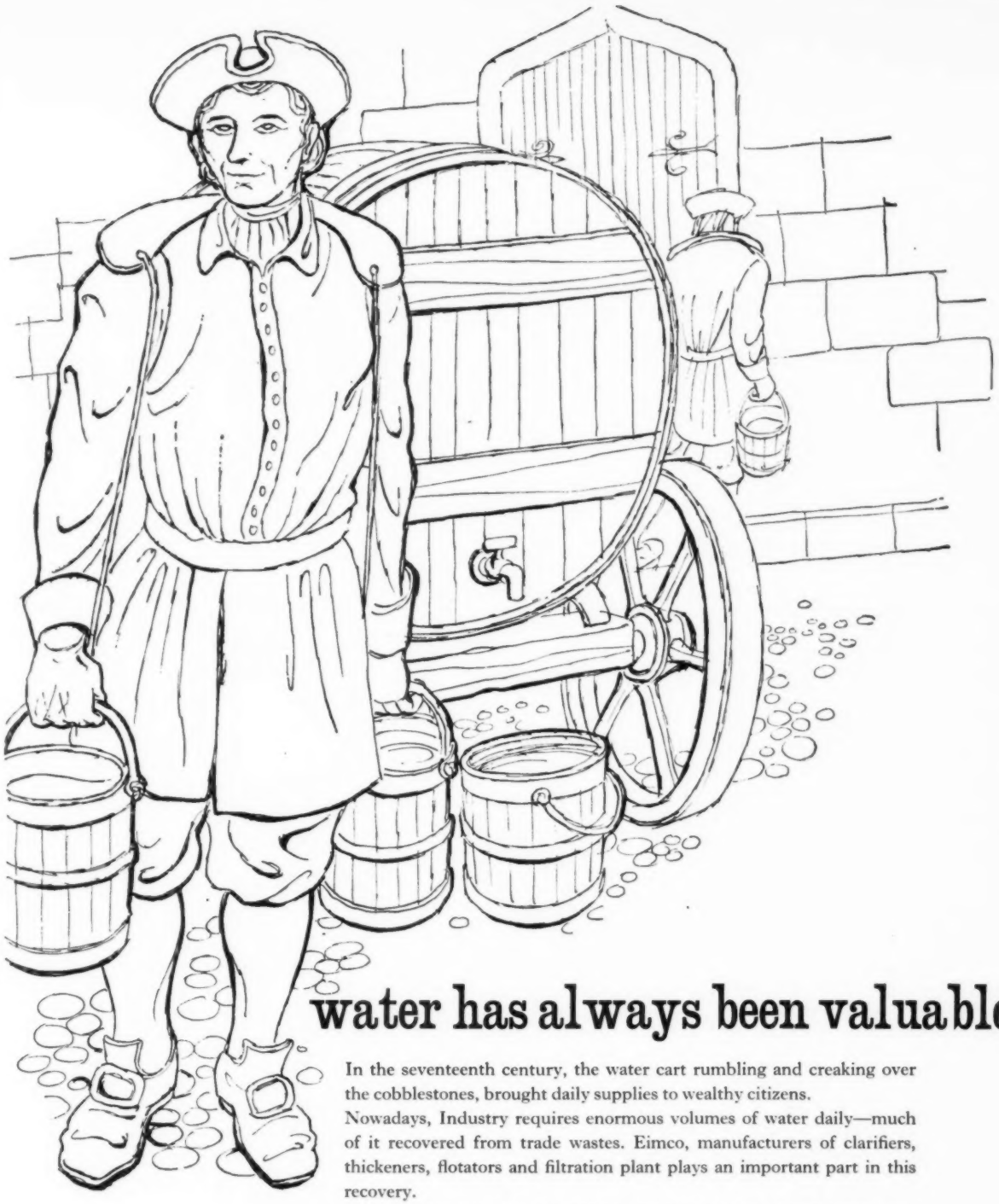
IN an underground gas reservoir comprising a gas-water-sand system, the dynamics of the gas bubble are a function of the compressibility of the water as the gas pressure functuates. It is a radial-flow moving boundary problem. The time-varying gas bubble pressure controls the gas bubble dynamics as well as the pressure variation in the porous matrix. The gas bubble radius at a given instant depends upon the history of the gas bubble pressure which causes water to move against the flow resistance provided by the porous matrix.

An analogue simulation method for solving this type of problem has been developed by H. D. Yoo of International Business Machines Corporation Research Center.* Using an electronic differential analyser, the method makes use of the readily-available fixed radius solution to simulate the moving boundary subject to an arbitrary pressure. The moving boundary problem is considered as a slow time-varying system of which the coefficients are adjusted continuously to new conditions as the boundary moves. The method can be applied to other moving boundary problems with an arbitrary input when a similar mathematical formulation can be made, and it can also be used as a data analysis technique when the process parameter is changing.

IBM Research Report RC-443.

Dust Problems in Modern Finishing Shops

SEVERE dust problems often occur in modern finishing shops designed with costly air purification systems, whereas frequently old-fashioned paint shops are practically dust-free. According to K. H. WATSON of Anti-Dust Services Ltd., speaking at the Industrial Finishes Convention held in May, this arises because in modern shops with hard, dustless floors and smooth glossy walls, the only place for dust to settle is on the wet finishes. Although air purification systems may remove 90 per cent of the airborne dust, other sources arise from personnel—particularly if supplied with freshly-laundered cotton overalls—from material, and upon the articles to be



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finished. In the more primitive finishing shop, on the other hand, oil, grease and overspray paint on the floor and walls act as dust traps. MR. WATSON'S recommendations are: build the finishing shop alongside the press shop, to draw warm air from it through as big an area as possible. The air should pass through a large expanse of dust barrier curtaining to even out localised draughts and to enable large dust particles to settle out. The floor, of rough concrete to give a broken surface, should be kept thoroughly oiled. Extreme care should be taken to ensure that there are no ledges or pipes out of reach directly over the actual finishing line—where dust could agglomerate in large particles to fall on, and spoil, the workpieces below. The walls and as many other surfaces as possible would be kept tacky. Tack-rags would be used to remove dust not only from articles to be finished but also on containers and all other items brought in.

Systematic Leak Inspection in Water Undertakings

MANY water undertakings are using inspection cycles which are uneconomically long—from $2\frac{1}{2}$ to 16 times as long as the cycles that would give the lowest combined cost of inspection and leakage: this is the conclusion of a mathematical analysis on systematic leak detection sponsored by the Water Research Association.*

As inspection is made less frequently its cost goes down, and cost of water waste rises. The combined cost is therefore likely to be a minimum at some particular frequency of inspection depending on the characteristics of the system under consideration. The analysis takes into consideration the following factors: total wastage from mains and services separately; cost of a single complete inspection cycle; cost of present waste; rate at which new leaks start; proportion of leaks found by inspection; and the manner in which leaks develop with time.

Comparatively simple mathematical expressions are derived for the average waste flow rate in a district over the inspection cycle, the duration of the inspection cycle for minimum combined cost, and the ratio of the lowest possible combined cost to the cost when no inspection is done.

If the system is not inspected frequently enough, the saving in inspection cost may well be a very small proportion of the cost of the water wasted. In systems where leaks are fast-growing and the rate of change of growth is small, there may be no inspection fluid at which the combined cost is a minimum.

*J. A. COLE, W.R.A. Technical Publication No. 18.

Sprayed Metal Protective Coatings on Steel

EXPERIMENTS on the protection of steel by sprayed aluminium and zinc coatings have been in progress at the British Iron and Steel Research Association since 1940. In a paper presented before the Industrial Finishes Convention at Earls Court in May, J. F. STANNERS has summarised some of BISRA's findings. In particular, the mechanism of failure of aluminium and zinc coatings is completely different.

Aluminium coatings, when they reach the end of their useful life, look almost as thick as when they were first put on, but beneath the coating, which comes away in flakes, is a build-up of white corrosion products which soon wash away leaving the steel exposed. In the case of zinc, the coating itself gets progressively thinner until it is corroded away to expose the bare steel.

In the case of aluminium, observations at BISRA support the view that protection is provided by a barrier built up of the sprayed metal and its corrosion products. The aluminium fails when its corrosion products disrupt the coating from within. Zinc, on the other hand, provides cathodic (i.e., sacrificial) protection; zinc corrosion products do not build up and rupture the coating. MR. STANNERS suggests a study of the formation of the different corrosion products might lead to the finding of a metal coating that combines the excellent barrier layer produced by sprayed aluminium with the cathodic protection and preferable form of the breakdown given by zinc.

The thinnest place on a sprayed metal coating is likely to fail first. Consequently surface roughness affects the life of coatings, particularly aluminium coatings. Tests at BISRA have shown that even on carefully prepared laboratory test pieces the peak-to-trough height can often be 2 or 3 mils or more. In the case of zinc coatings, roughness or irregularities in thickness will have less effect because zinc on the neighbouring hills round a thin point will be able to protect the steel after the thin area of coatings has corroded through to the metal.

Graphite Textiles for Industry

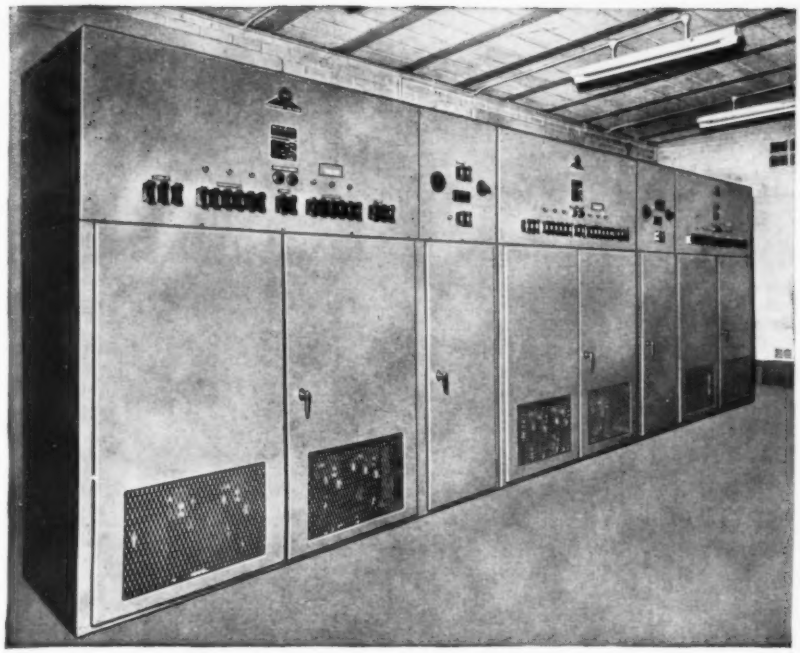
DURING the last three years, woven fabrics, felts and yarns composed of graphite fibres have come on to the market. Developed by the National Carbon Company of America as part of a programme of research for new materials to withstand the severest high temperatures encountered in nuclear energy, missile and space vehicle applications, they are finding increasing uses in industry. Low expansion coefficient, good thermal conductivity and relatively low elastic modulus make for exceptional resistance to thermal shock. Being electrically conductive and having high emissivity at low temperature, they are well suited for electrical heating elements; a graphite fabric element has been used as an immersion heater, with an output of 6500 watts/cm. Very lightweight textiles are being made for incorporating in wall and ceiling panels as heater elements. Graphite textiles have also been used for higher temperature heating applications applied locally, for the brazing of stainless steel honeycomb sandwich structures at 950°-1050°C; and for brazing niobium in vacuo at 1820°C.

Graphite textile material is being used for furnace conveyor belts (requiring a neutral or reducing atmosphere), and graphite felts and waddings are used for thermal insulation. For insulating furnaces, it is possible to obtain a more rigid material by impregnating the felt in liquid hydrocarbon and then carbonising it.

Graphite fabrics have interesting possibilities as electrical conductors in corrosive environments. In this connection a development is under way for the removal of dust from hot and corrosive gases which should be more economical both in first cost and in running costs than the conventional electrostatic precipitator.

In the form of yarn—introduced only in April this year—graphite fibres are being applied to the sealing of pumps in the chemical industry. Their self-lubricating properties, better heat elimination and lower thermal expansion than conventional packing materials, render them particularly suited to this field.

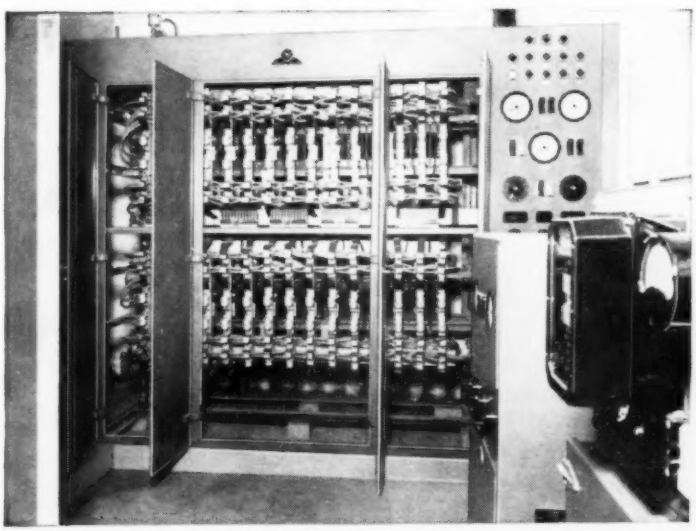
To date, graphite fibre materials have been made by calcining purified and regenerated cellulose compounds which are already in the form of spun threads, woven fabrics or felts before they are introduced into the furnace, where they carbonise without melting. No attempt has yet been made to produce continuous graphite filament or graphite flock.



A 1300 kW bank of Hewittic Germanium Rectifiers installed in the Shipyard of Messrs. Cammell Laird & Co. (S & E) Ltd., Birkenhead, for providing D.C. for shore to ship supply.

Germanium

rectifiers



A 6000 amp Hewittic Water-cooled Germanium rectifier providing a continuous output at 100 volts D.C. for an electrochemical process at the Luton works of Laporte Industries Ltd.

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33rd International Congress of Industrial Chemistry

BORDEAUX is this year's venue of the 33rd International Congress of Industrial Chemistry, which will be held between 1st and 8th October.

This Congress will be preceded by a three-day European Conference of Chemical Engineering, which will be held at Toulouse from 28th to 30th September.

Both events are jointly organised by the Société de Chimie Industrielle and the Society of Chemical Industry.

The main contributors to the Chemical Engineering Conference will be: PROF. K. G. DENBIGH on solid-gas reactions; PROF. B. F. DODGE of Yale, on the influence of pressure on the behaviour of matter; PROF. D. M. NEWITT, on selection of drying equipment; PROF. T. H. CHILTON of California, on the future of mass transfer processes.

Delegates wishing to attend should register before 11th September. Full details may be obtained from: Secrétariat Général, Bourse Maritime, place Lainé, Bordeaux, France.

Hungarian Continuous "J"-Diffusion Juice Extractors in Service

IN 1957 a prototype continuous diffusion process for extracting juice from sugar beet, developed by the Research Institute for the Hungarian Sugar Industry, was put into operation.

Experience has shown that the new "J"-type equipment provides, (*a*) good exhaustion while maintaining normal draft, (*b*) good quality raw juice easily clarified, (*c*) full operational safety, (*d*) lowest fresh water requirements, elimination of waste water, (*e*) lowest electrical and heat energy consumption, (*f*) simplicity of design and operation, (*g*) automatic operation, (*h*) reduced space requirements, and (*j*) low investment costs. As a result, "J"-diffusion equipment is to be introduced gradually into all Hungarian sugar factories; orders from abroad have also been received. The first two production plants, the J-1V type with a daily throughput of 700-750 tons, were commissioned in 1959.*

The production J-1V plant occupies only 68 sq. m. floor area, and has an overall height of about 17.5 metres, so that it can be installed inside a factory building. A new feature is the mixed feeding of pulp press water and pressure water by a single pump, from hydrodynamic and control considerations. This arrangement is also economical in heat requirements.

The first production J-1V plant, installed in the Sarkad sugar factory in parallel with an existing Robert diffusion battery, worked without interruption for 124 days from October 16 1959 to January 17 1960. The quality of raw juice was excellent throughout, though the beets processed towards the end of the campaign were of inferior quality. High extraction rates were obtained, with sugar loss of 0.25 per cent when pulp press water return was in operation. Automatic temperature control of the J-1V apparatus resulted in mesophile germ counts lower by one order of magnitude than that of the Robert battery.

Good extraction, good quality raw juice and indifference to beet quality have led to growing interest in J diffusion apparatus. A new prototype equipment for a daily throughput of 1500 tons was put into operation last year in Hungary with a view to laying down a production line this year.

*MICKLOS TEGZE, Hungarian Heavy Industries, Spring 1961, p. 19.

DIARY

European Organisation for Quality Control

September 11-13. The 5th International Congress will be held in Turin, Italy. Further details from E.O.Q.C. Weena 700, Rotterdam, Holland.

Association Internationale de Cybernétique

September 11-15. The 3rd International Congress on Cybernetics will be held in Namur, Belgium. For particulars write to: Association Internationale de Cybernétique. 13, rue Basse-Marcelle, Namur, Belgium.

Instrument Society of America

September 11-15. The 16th Instrument-Automation Conference and Exhibition will be held at Los Angeles, U.S.A. Further details can be obtained from: I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

September 14-20. The International Conference on High Energy Physics will be held at Aix-en-Provence in France. The Conference is sponsored by the Secretariat, Scientific Conferences, CERN, Geneva, 23, Switzerland.

American Institute of Chemical Engineers

September 24-27. The 46th National Meeting will be held at the Lake Placid Club, Lake Placid, N.Y., U.S.A.

National Industrial Fuel Efficiency Service

September 25-29. The 8th Annual Refresher Course on Current Practice in Fuel Efficiency will be held at the Clarendon Laboratory, Oxford. The preliminary programme and registration form is available from: Ailsa House, 181 King's Road, Reading.

British Paper and Board Industry Research Association

September 25-29. The 2nd Fundamental Research Symposium will be held in Oxford. Write to: B.P.B.I.R.A., St. Winifred's Laboratories, Welcomes Road, Kenley, Surrey, for further particulars.

Institution of Heating and Ventilating Engineers

September 27-October 4. An International Conference on Heating, Ventilating and Air Conditioning will be held at Olympia, London. Write to: I.H.V.E., 49 Cadogan Square, London, S.W.1, for further details.

September 30-October 7. Basel is the location of the 2nd International Congress on Industrial, Trade and Domestic Waters, and Technical Exhibition. Further details from: Pro Aqua, A.G., Postfach, Basel 21, Switzerland.

Institution of Chemical Engineers

September 16-October 1. Graduates and Student Section, Overseas Industrial Tour 1961 to Italy.

October 19-20. The 1961 Symposium of the Graduates and Students Section, on "Scale-up" and "Pilot Plants," will be held at Royal Overseas League, St. James's, London, S.W.1.

October 20. Annual General Meeting of the Graduates and Students Section at **9.30 a.m.**, at the Royal Overseas League, St. James's, London, S.W.1.

International Institute of Welding

October 2-6. The 3rd International Metal Spraying Conference will be held in Madrid, Spain. Further details from the Director, Spanish Delegation, I.I.W., Serrano 144-A, Madrid.

INTERNATIONAL MINERAL PROCESSING CONGRESS – CANNES 1963

THE previous meeting held in London in 1960 definitely stamped this Congress as a representative and authoritative gathering and the published Proceedings form a most important part of the literature of mineral processing. The mining industry has lagged far behind the chemical industry in continuous automatic control but a combination of circumstances now makes rapid development almost inevitable. After the spectacular hydrometallurgical developments in the uranium industry and the initial success of pressure leaching techniques in Canada, this branch of mineral processing seems to have quietened down. However, experts are agreed that increasing dependence on complex ores points to a wider use of chemical methods of treatment.

It is in these last two fields that the overlap between the chemical and mineral technologies is greatest and the methods, experience and approach of chemical engineering have already been widely applied. For these reasons the coming Congress at Cannes promises to be of especial interest to chemical engineers.

The organisation of the Sixth Congress, which will be held from 26th May to 1st June, is in the hands of la Société de l'Industrie Minérale and the executive committee is composed as follows:—

President: MONSIEUR R. J. TESTUT.
General Secretary: MONSIEUR PIERRE GY.
Members: MESSIEURS ASTIER, EMERY, PLOIX, REY, SAINT-GUILHEM, SAVEROT, SEYER, VIELLEDENT and VUCHOT.

The Congress will embrace all aspects of mineral processing and papers will be selected solely on the basis of their scientific value. It is desirable however, that emphasis be placed upon the following subjects.

1. The concentration of iron minerals including magnetic roasting but excluding agglomeration.
2. Measurement, control and automation.
3. Hydrometallurgy.

Importance is also attached to the economic aspects of mineral processing and authors will be encouraged to include data on installation and operating costs and on cost comparisons where alternative processes are available.

Those wishing to submit papers should send a plan and a summary of the intended topic together with a note on the original aspects and conclusions of the work to the Representative for the United Kingdom and the Commonwealth, PROFESSOR M. G. FLEMING, Royal School of Mines, Prince Consort Road, London, S.W.7, before 15th October, 1961.

The official languages will be French, English, Russian and German. Papers may be presented in any of these languages and, during the sessions, the discussions will be simultaneously translated into the other three languages.

During the week following the sessions at Cannes, series of visits will be arranged to plants and laboratories in France, Yugoslavia, Italy, Morocco, Spain and Portugal.

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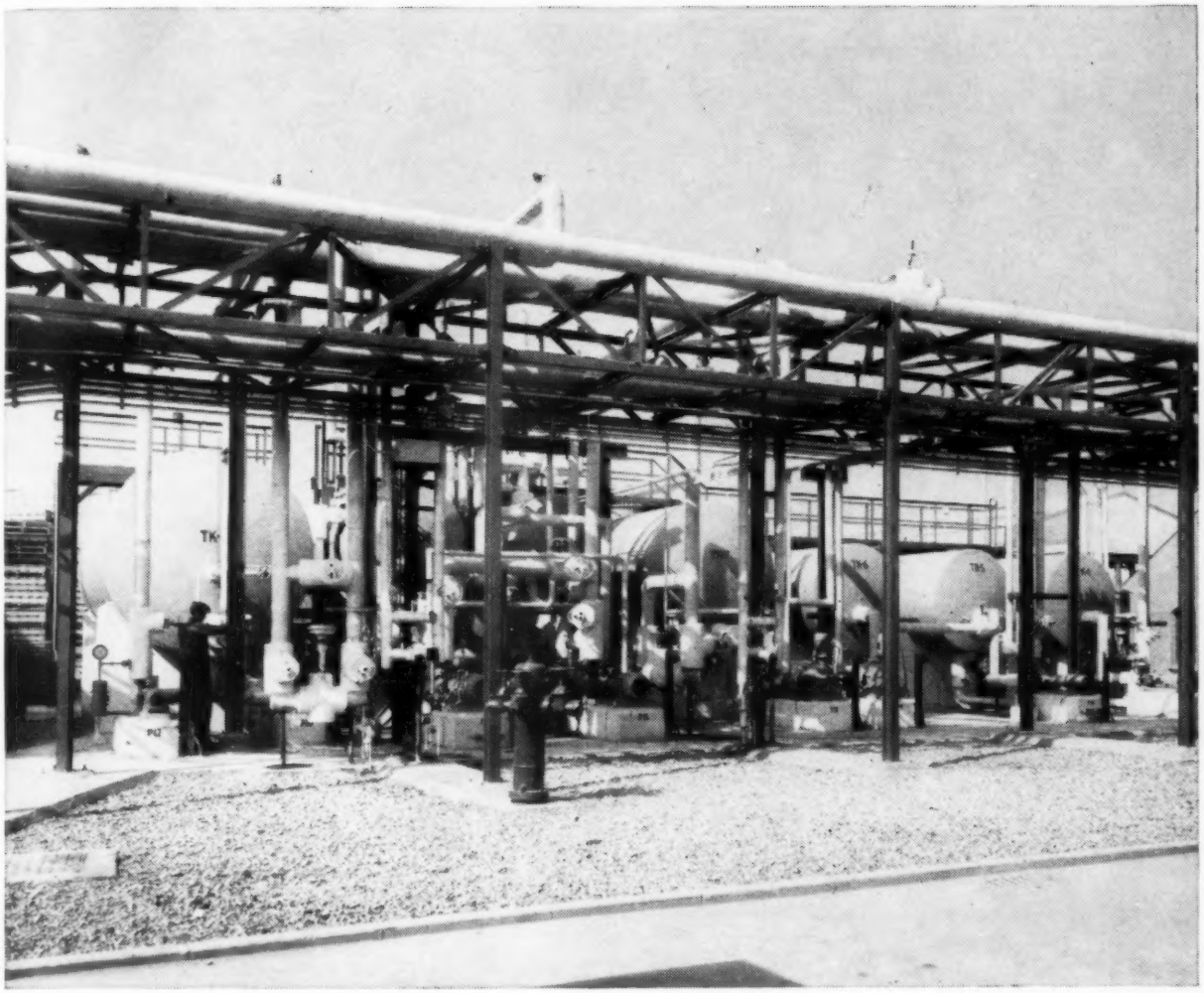

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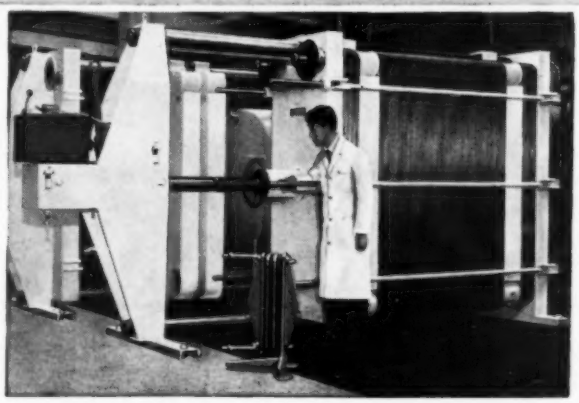

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British Chemical Engineering
A HEYWOOD PUBLICATION

Particles—Boon and Nuisance

FINE particles, by which is understood particles that are tangible to the senses but yet are very small compared with the dimensions of normal environment—particles which are larger than molecules but smaller than gravel—effect profoundly many aspects of man's existence. This can be attributed to the fact that properties possessed by materials in the finely divided state differ significantly from the bulk state properties.

Obvious examples of this divergence come to mind; the accentuation of such surface-dependent properties as chemical reactivity and surface forces—the reason why substances which are normally innocuous, such as iron, sugar and flour, can be highly reactive or explosive in the pulverized state. Another example is the Brownian movement, a phenomenon which is useful in high-efficiency air filters, since this zig-zag motion causes very small particles to strike and adhere to the filter fibres. Finally, there is the greatly reduced resistance to movement which magnifies the effects of fluid and thermal friction and of electrostatic fields.

The industries embracing chemical, petroleum and mineral processing produce, handle and collect millions of tons of finely divided matter every year, where they are important as products and as process tools. Indeed, a great deal of the output of the refinery and petrochemical industries would be impossible without their use, a point emphasized by the widespread use of the fluid-bed catalytic reactor. Although this is one of the more spectacular process applications, there are many others extending from simple gravity sand filters, through the various mass transfer processes, to the newly-developed techniques of gasification, carbonization and oxidation of coal in fluid beds, which already are approaching commercial stature.

Among the products and intermediates of the above industries, the influence of fine particles is especially conspicuous; this is reflected in the host of techniques used for making or handling fine particles, and such processes as crushing and grinding, crystallization, precipitation, explosive disintegration, polymerization, emulsification, spray drying and others are commonplace.

In the sphere of mineral beneficiation, fine particles also play a vital role and determine the character of a whole range of separation processes. Thus the desired constituents of an ore often occur as discreet particles within it; hence one necessary stage in the process of beneficiation is to reduce the ore particle size to such an extent that the individual grains can be freed from one another. They may then be separated by processes which are based upon physical or chemical properties of the particles. Typical of the nature of particles is the fact that the effectiveness of the most important method of separation, flotation, can be influenced by the earlier treatment the particles have undergone. Sometimes it is necessary for the particles to have a uniform composition across their mass, and at others their surfaces must be treated. For example, flash roasting of pyritic ores produces a magnetic skin which assists the separation processes, whereas other ores oxidize so rapidly when crushed that separation must be immediate, otherwise the oxide film prevents effective flotation.

Apart from their eminently useful properties, particles also have some awkward ones. Because of their size they are elusive, and their capture, for example to avoid air pollution, sometimes requires the use of expensive equipment. Perhaps less obvious, but equally troublesome, is the scaling of heat-transfer surfaces, such as occurs when calcium sulphate crystallizes through its inverse solubility with rising temperature. To date no entirely satisfactory solution has been found for this problem, but some drastic suggestions have been made. One is to spray molten metal into an enclosed vessel in order to generate steam, so that the solidified metal pellets become coated with scale which, on remelting, forms a slag and is readily removed. Another is to use inert solids as heat transfer media in a fluidized bed as a means of evaporation. A second fluidized bed, fed by combustion gases, would supply heat to the particles, while scale build-up would then be loosened by tumbling.

Often the mere handling of particles is difficult, particularly if the materials are inflammable and toxic. Microencapsulation (i.e., the enclosure of small particles in minute capsules of a polymeric material) offers a convenient solution to problems of this kind, although so far the use of this technique has been limited to the production of vitamins.

The remarkable thing is that, despite the high level of fine particle technology and its many new and exciting applications, our fundamental knowledge is still quite limited. In fact, we know far more about the force fields in the invisible molecule and atom than we do about the corresponding fields around visible fine particles. Most of our knowledge, therefore, must be classified as empirical. In view of what has been achieved, it is certain that we can expect some remarkable advances once we are better equipped fundamentally. For this reason such conferences as the forthcoming Size Reduction Conference, to be held next Spring at Frankfurt, are to be welcomed.

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THE APPLICATION OF PARTITION ANALYSIS FOR THE EVALUATION OF DISTILLATION PLATE PERFORMANCE

A general graphical analysis of the mixing processes that are operative on an actual distillation plate is presented. A graphical procedure has been developed for the design of the fractionating column on the basis of the partition equivalent of the constituent distillation plate, a characteristic that is capable of independent evaluation

by G. NARSIMHAN

THE design of fractionating columns is usually based on the assumption that each distillation plate is an ideal one in which complete mixing of the vapour and liquid reflux provides equilibrium streams which leave the plate. This is not a true representation of the conditions existent on the plate. The liquid reflux enters the tray at one extreme section of the plate and receives successive contacts with fresh vapour discharged from the lower tray. In estimating the overall efficiency of the plate, it is necessary, therefore, to take into account not only the efficiency of contact between the vapour and the liquid at one point, but also the effect of the gradual change in the composition of the liquid as it flows across the plate. The presence of concentration gradients in the liquid on the distillation plate has been long recognized.[1, 3, 5, 6] The investigations of LEWIS[6] were based on the assumptions of linearity of vapour-liquid equilibria, constancy of molal vaporization and reflux rates and uniform vapour composition. KIRSCHBAUM[5] based his analysis on the plausible assumption that the distillation plate may be considered as equivalent to numerous pools of liquid moving down the plate after discrete and successive equilibrium contacts with fresh vapour delivered from the lower plate. This kind of approach did not receive much favour from later investigators, probably because of the complicated nature of the assumption proving difficult design procedures. The later work of GAUTREAUX[3] is based partly on the assumptions of LEWIS and KIRSCHBAUM.

A further extension of the pool concept has been developed by MARANGOZIS and JOHNSON.[7] Another approach to the problem of liquid mixing is based on the supposition that mixing takes place by an eddy diffusion mechanism. Most of the activity in this field has been centred at the Massachusetts Institute of Technology. In the recent work of GILBERT,[4] experimental frequency-response results have been presented and are interpreted by the diffusion equation. OLIVER and WATSON[8] have assumed yet another mechanism and supposed that a fraction of the liquid at the exit weir is circulated to the inlet weir, where it is mixed with the incoming liquid. FOSS *et al.*[2] in their elegant analysis have resorted to tracer techniques for measuring the distribution of residence times for the liquid. Surprisingly enough, the derived expression is identical with the one derived on the basis of pool concept.[3]

The mechanism of interaction between the vapour and liquid on a distillation plate is highly complex. However, the assumption that, in an ideal plate, the liquid leaves the plate in equilibrium with the vapour, though far reached from actual conditions, provides a convenient standard for the comparison of actual plate performances. In as much as the oncoming vapour, assumed to be of uniform composition, has to contact liquid whose composition varies from end to end, the vapour leaves the plate with composition changing from point to point. If the vapour-liquid contact is assumed ideal, providing equilibrium streams after interaction, it is possible to look upon an ideal plate, in one extreme, as consisting of an infinite number of liquid pools moving across the plate after successive differential contacts with fresh vapour. In the other extreme, it conforms to the definition of a theoretical plate in that the entire liquid and vapour react towards a final equilibrium. The actual behaviour of the plate is something in between the two theoretical extremes, with the added difference that the vapour-liquid contact provides non-equilibrium streams due to the existence of a finite local efficiency. The method of partitioning the tray and assuming each compartment to behave ideally has been suggested.[5] The present analysis represents considerable improvements over that of KIRSCHBAUM in that it has taken into consideration the non-uniformity of the oncoming vapour and the influence of local efficiency on the vapour-liquid contacts in all the compartments. In addition, being a graphical method, the assumption of linear equilibrium relationship is dispensed with.

G. NARSIMHAN took his Ph.D. at Nagpur University, India, and subsequently studied at California University. He is now at the National Chemical Laboratory, Poona.

Development of Graphical Procedure

The graphical procedure which is developed below is essentially based on material balance for the more volatile component in each compartment. As against the method of KIRSCHBAUM, the behaviour of the plate is assessed on the basis of fluid streams leaving the plate after appropriate contact over an arbitrary number of compartments.

Fig. 1 represents a section of the equilibrium diagram for the system: $C_6H_5 . CH_3 - CCl_4$ at a total pressure of 740 mm. The data have been taken from a handbook. The operating line *R-R* is drawn for unit reflux ratio with product composition at 80 mol per cent CCl_4.

Consider the transfer process when a stream of vapour of uniform composition Y_{n+1} is about to contact liquid of composition X_{n-1} about to flow across the plate. Complete mixing of all the vapour and liquid under ideal conditions results in streams of composition Y_n and X_n leaving the plate. If V and L represent the molal vapour and reflux rates, writing the material balance for the more volatile component:

$$(V . Y_{n+1} + L . X_{n-1}) = V . Y_n + L . X_n \quad \ldots . (1)$$

or

$$(Y_{n+1} - Y_n) = \frac{-L}{V} (X_{n-1} - X_n) \quad \ldots . (1a)$$

The point on the equilibrium curve representing the vapour-liquid streams leaving the plate is obtained by drawing a straight line of slope equal to $-L/V$ from the reference point A' representing the fluid streams about to contact each other, and allowing it to intersect the equilibrium curve at B. If a local efficiency, E, is assumed for the vapour-liquid interaction process, the straight line would terminate at some intermediate point such that the ratio of the appropriate segments would equal E.

Procedure for Single Partition of a Plate

The procedure indicated above may be repeated for one partition, giving rise to two compartments, for each of which material balance similar to Equation (1) may be written. The sketch at the foot of Fig. 1 represents this partitioning. The imaginary partition divides the plate into two imaginary compartments, in each of which transfer processes proceed towards equilibrium. The liquid reflux of composition, X_{n-1}, completely mixes with half the quantity of the vapour of composition, Y_{n+1}, delivered from the lower plate and provides two equilibrium streams of liquid and vapour, of composition X_2^1 and Y_2^1, the former moving down the plate to contact the rest of the vapour and the latter being discharged from the plate. Again, in the second compartment, the transfer process moves towards equilibrium, providing two equilibrium streams of composition, X_2^2 and Y_2^2, the former being discharged to the plate below and the latter to the plate above. If complete mixing is assumed for the vapour in the intervening space between plates, the composition of the vapour leaving the plate will be given by the mean composition $(Y_2^1 + Y_2^2)/2$. Material balance for the above case may be written as:

$$\frac{V}{2} Y_{n+1} + L . X_{n-1} = \frac{V}{2} Y_2^1 + L . X_2^1 \quad \ldots . (2)$$

or

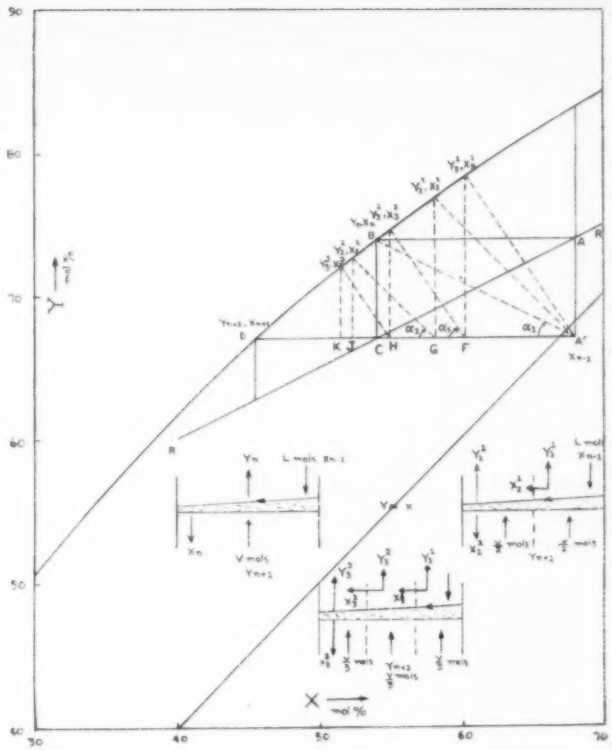
$$(Y_{n+1} - Y_2^1) = \frac{-2L}{V} (X_{n-1} - X_2^1) \quad \ldots . (2a)$$

$$\frac{V}{2} Y_{n+1} + L . X_2^1 = \frac{V}{2} Y_2^2 + L . X_2^2 \quad \ldots . (3)$$

or

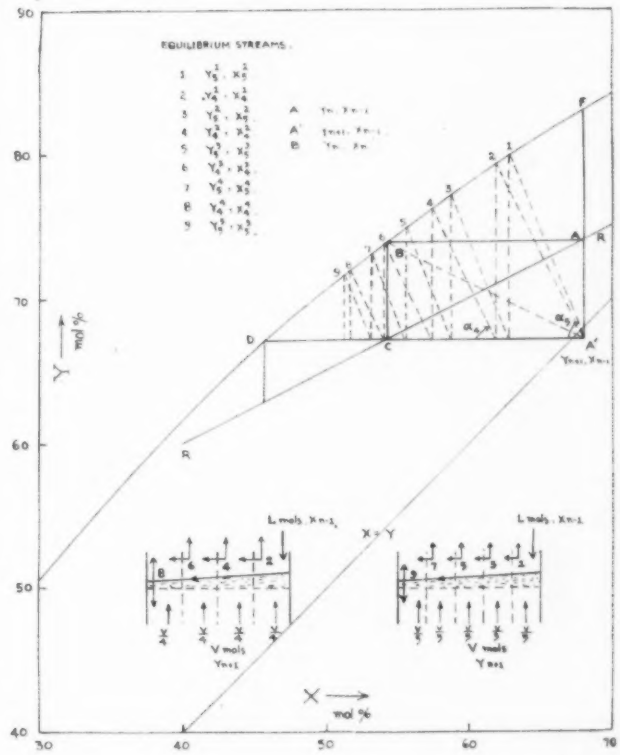
$$(Y_{n+1} - Y_2^2) = \frac{-2L}{V} (X_2^1 - X_2^2) \quad \ldots . (3a)$$

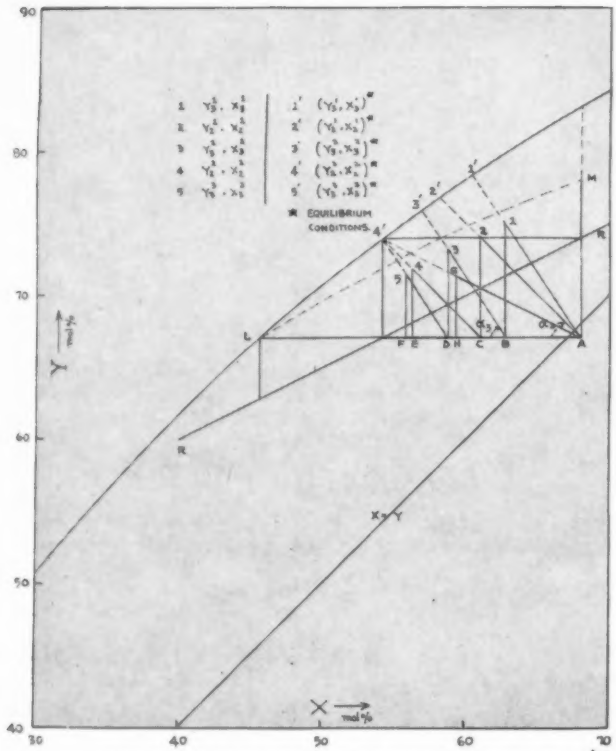
The equilibrium compositions corresponding to (Y_2^1, X_2^1), (Y_2^2, X_2^2) may be located on the diagram by successive points



1 *Equilibrium streams in partitioned tray for uniform vapour composition. Partitions:* 0, 1 *and* 2.

2 *Equilibrium streams in partitioned tray for uniform vapour composition. Partitions:* 3 *and* 4.





Non-equilibrium streams in partitioned tray for finite local efficiency. Partitions: 0, 1 *and* 2. *Local efficiency:* 0.7. **3**

It is evident from an inspection of Fig. 2 that the value given by the above equation corresponds to the maximum enrichment possible for the vapour discharged from the lower plate. This part of the graphical analysis somewhat corresponds to the analytical treatment of LEWIS.[6]

Allowance for Finite Local Efficiency

Since for an actual plate the local efficiency is never 100 per cent, modification in the graphical procedure is necessary to account for a finite local efficiency thereby permitting a graphical design procedure to be developed for a fractionating column. In the present investigation, the graphical procedure has been extended to take into account the effect of finite local efficiencies, 50 per cent, 70 per cent and 90 per cent, on the composition of the vapour and liquid streams leaving each compartment and therefore on the overall efficiency. In the case of multiple equilibrium contact, the overall efficiency of the plate will always be greater than 100 per cent because the composition of the vapour leaving any partitioned plate is higher than Y_n, the vapour composition corresponding to a no-partition or ideal plate. But in the case of non-equilibrium contact, the overall efficiency may or may not be greater than 100 per cent.

Graphical Procedure for Stream Composition

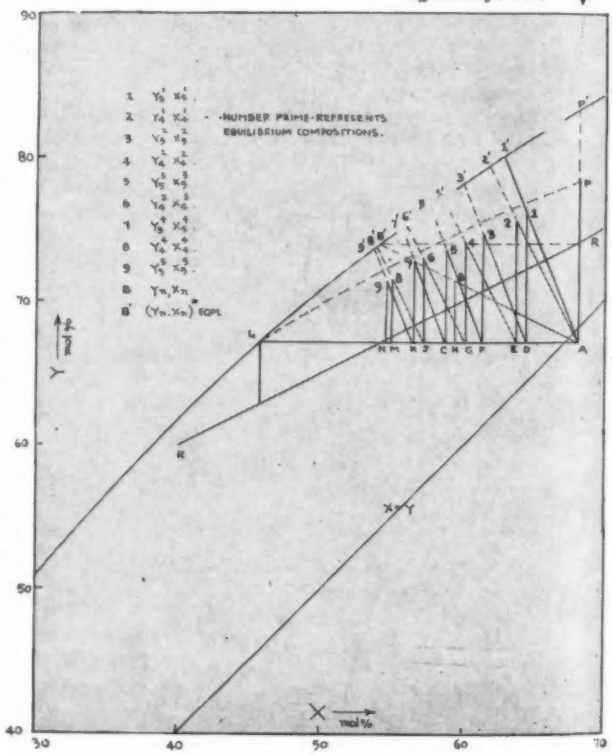
The graphical procedure for determining the composition of streams leaving imaginary compartments after finite contact will now be indicated. The operating point will still be A'. Fig. 3 summarizes the procedure for 0, 1 and 2 partitions for a local efficiency of 70 per cent. The composition of the vapour leaving an ideal plate, with no partition, will be given by drawing a straight line from A' with a slope equal to $(-L/V)$ and reading off the composition at an intermediate point G such that the ratio of segments

of intersection on the equilibrium curve with straight lines drawn from the operating point A', with slope equal to $(-2L/V)$ and then from an appropriate point from the base line passing through A'. This procedure is evident from Fig. 1. The material balance equations are verified through a consideration of similar triangles formed in the graphical construction. It is apparent from the figure that the mixed mean composition of the vapour discharged from the plate is richer, in composition, than that of the vapour leaving an ideal plate.

The above procedure may be repeated with the help of appropriate equations defining the material balance for the more volatile component in each of the imaginary compartments formed by partitions numbering 2, 3, 4, etc., up to infinity. The graphical procedure for locating the equilibrium streams leaving each compartment is the same as indicated earlier for one partition plate. The starting point is always A'. The slope of the straight line drawn from A' to start with and then from appropriate points located on the base line is $(-n \,.\, L/V)$, where n is the number of imaginary compartments. The graphical procedure is indicated in Figs. 1 and 2 for compartments up to 5. In each case the average composition of the vapour leaving the plate will be given by adding the ordinate values corresponding to equilibrium compositions and dividing by the number of compartments. In the case of infinite number of partitions, the slope of the process lines will be infinity and the composition of the vapour leaving the tray will be given by the integral:

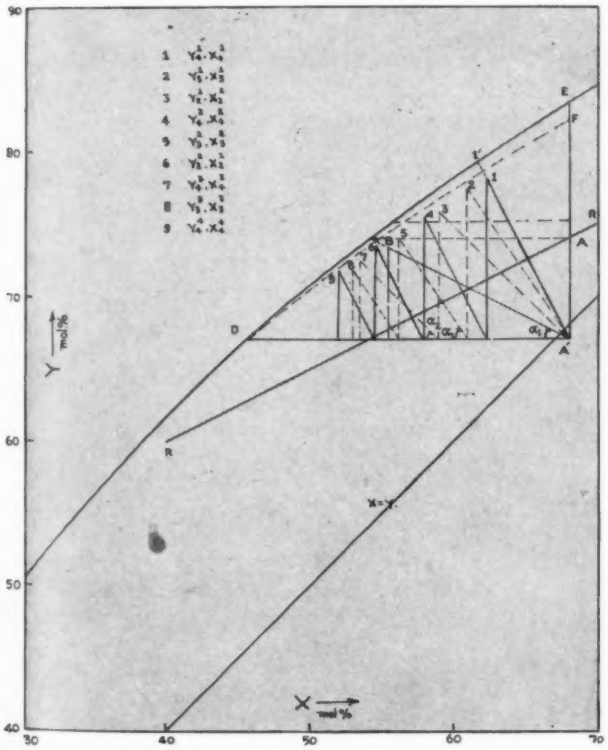
$$\underset{p\to a}{Y_{av}} = + \frac{1}{(X_{n-1} - X_{n+1})} \cdot \int_{X_{n+1}}^{X_{n-1}} Y \,.\, dx \qquad \ldots.(4)$$

Non-equilibrium streams in partitioned tray for finite local efficiency. Partitions: 3 *and* 4. *Local efficiency:* 0.7. **4**

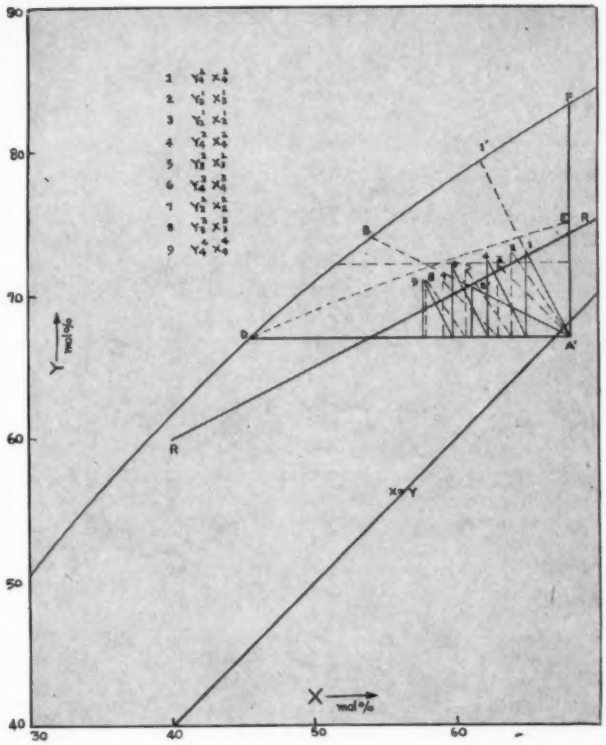


($A'G/A'4$) equals 0.7. In the case of a single partition, the line drawn from A' has a slope equal to $(-2L/V)$ and terminates at point 2 such that ($A'2/A'2'$) equals 0.7. 2′ represents a point on the equilibrium curve that would be reached for 100 per cent local efficiency. A perpendicular is drawn from point 2 to the base line AL, corresponding to uniform vapour composition, Y_{n+1}, to intersect at C. C represents the composition of the liquid leaving the first compartment and that of the vapour from the lower plate. The interaction between these two streams will be followed on a line drawn from C with a slope again equal to $(-2L/V)$ and terminated by a point 4, such that the ratio of segments ($C4/C4'$) equals 0.7. A similar procedure may be adopted in the case of other partitions. For two partitions, the sequence will be $A'1B3D5$, the composition of the fluid streams leaving each of the three compartments being given by 1, 3 and 5. For three and four partitions the slope of the process lines will be respectively $(-4L/V)$ and $(-5L/V)$. The progress lines will be arrested as soon as 70 per cent of theoretical enrichment is attained. The equilibrium compositions will be indicated by primed numerals. The composition of the fluid streams leaving each compartment will be given by points 2, 4, 6 and 8 in the case of three partitions and by 1, 3, 5, 7 and 9 in the case of four partitions. For infinite partitions, involving finite differential contact with a local efficiency of 70 per cent, the average composition of the vapour leaving the tray will be given by the mean height of the curve LM from the base line $Y = 0$. The curve LM is drawn in such a way that any vertical drawn from the equilibrium curve to the base LA will be intersected by the curve LM at a point corresponding to 0.7 times the total height. The area under the curve LM and the base AL will therefore be 0.7 times the area under the equilibrium curve and the base AL.

Figs. 5 and 6 indicate the graphical procedures for 0, 1, 2 and 3 partitions and 90 per cent and 50 per cent local efficiency.



5 *Non-equilibrium streams in partitioned tray for finite local efficiency. Partitions:* 0, 1, 2 *and* 3. *Local efficiency:* 0.9.



6 *Non-equilibrium streams in partitioned tray for finite local efficiency. Partitions:* 0, 1, 2 *and* 3. *Local efficiency:* 0.5.

Use of Partition Equivalent

From all the figures the average composition of the vapour leaving the plate is calculated and plotted as functions of number of partitions and local efficiency. Fig. 7 represents this functional relationship. From the figure, the composition of the vapour leaving an ideal plate is 74 per cent. The maximum enrichment possible for the vapour is for an infinite number of partitions and this is calculated as 76 per cent providing, for a vapour composition of 67 per cent for the vapour entering the plate from below, an overall plate efficiency 130 per cent. A straight line drawn from a point on the ordinate corresponding to 74 per cent will intersect the curves for different local efficiencies at partition numbers 1 and 5 corresponding to 90 per cent and 70 per cent efficiency, indicating thereby that for 90 per cent local efficiency a partition equivalent of one for an actual plate will provide an overall plate efficiency of 100 per cent so that the normal McCabe-Thiele graphical procedure may be adopted to estimate the actual number of plates. Similarly, in the case of 70 per cent local efficiency, a partition equivalent of five is needed before the conventional procedure may be applied for the estimation of actual plate requirements. However, for 50 per cent local efficiency, the overall plate efficiency can never reach 100 per cent even at infinite partition equivalent, since the maximum concentration possible for the vapour is only 72.4 per cent, which is less than 74 per cent for an ideal plate.

Application of the Method for Variable Vapour Composition

The graphical procedure indicated above is based on the

important assumption that the vapour ascending from below the reference plate is completely mixed and is of uniform composition. In as much as this vapour is delivered from a plate possessing concentration gradients in the transverse flow of the liquid reflux, there is a distinct possibility of existence of concentration gradients in the vapour. The non-uniformity of vapour composition introduces difficulties in the application of the general graphical computation procedure developed earlier for uniform vapour composition. An attempt will now be made to develop an approximate method.

A preliminary graphical representation of the variable vapour composition across the plate will be necessary. This would involve analysis of the vapour tapped from various positions along the plate width. In Fig. 8 an arbitrary concentration distribution in the vapour is represented. The shape of the curve is mainly dictated by the direction of flow of reflux on the plate, the extent of lateral mixing and the vapour load which determines the magnitude of eddy currents in the vapour space. In the figure, the base O-W represents the width of the plate and the curve O-Y_w, the variable vapour composition, with reference to the existing ordinate. In order to compare the performance of a partitioned tray with that of an ideal plate, the point Y_w is chosen so as to coincide with the reference point A' of the previous cases. The base O-W is divided into two, three and such other segments so as to correspond to the number of imaginary compartments in the partitioned tray. In the figure, only two and three segments are shown to correspond to one and two partition equivalents respectively.

In the case of a single partition, from the point $\frac{1}{2}W$ on the base, which divides the base into two segments, a vertical is drawn to intersect the vapour curve, and provide two segments which would be accommodated in the two compartments. Since the basic idea in partitioning the tray is to look upon the vapour-liquid mixing in each compartment as an independent process, it is possible to assign average values for the composition of the vapour in each of the two compartments. These values, determined graphically, correspond to ordinate values at points 7 and P. The average composition of the vapour in the first compartment is 7 (65 mol per cent) and this vapour contacts fresh liquid flowing from the plate above the reference plate. To compute the composition of the vapour and liquid leaving the first compartment after equilibrium contact, the earlier procedure, based on material balance equation will be adopted. It is evident that a straight line drawn from the point 7 with a slope equal to $(-2L/V)$ will intersect the equilibrium curve at point 2 which at once gives the compositions of the fluid streams leaving the first compartment. Since the liquid stream enters the second compartment to contact the rest of the vapour, to follow the interaction process, the second point of reference is located by dropping a vertical from 2 to intersect the horizontal through P at P. Again a line with a slope equal to $(-2L/V)$ is drawn to intersect the equilibrium curve at 5, which gives the composition of the fluid streams leaving the tray. The average composition of the vapour will be given by the mean ordinate corresponding to 2 and 5.

Procedure for Plate in Three Compartments

For the case of a plate divided into three compartments, a preliminary determination of the average composition of the vapour stream accommodated in each of the three compartments will be determined graphically in a manner similar to that adopted for the earlier case of a single partition with two compartments. Perpendiculars drawn from points 1/3 W, 2/3 W, on the base divide the vapour curve into three segments and the average composition of the vapour in the three compartments will be given by 6, L and C. The starting point will be 6 and a line drawn with a slope equal to $(-3L/V)$ will intersect the equilibrium curve at 1, providing the compositions of the vapour-liquid streams leaving the first compartment. A perpendicular dropped from 1 will intersect the horizontal drawn through L at L. Again a line drawn from L with a slope equal to $(-3L/V)$ will intersect the equilibrium curve at 3, which will represent the composition of the fluid streams leaving the second compartment. The perpendicular drawn from 3 will intersect the horizontal through C at C. The final process of vapour-liquid interaction will be followed through a line drawn from C with the same slope as before. The fluid streams leaving the last compartment will be given by the point of intersection 4. The average composition of the vapour leaving the plate will be given by averaging the ordinates 1, 3 and 4. For the case of a plate divided into infinite partitions, the slope of the process lines will be infinity and the starting point will be Y_w. The liquid will leave the plate with a composition given by O and the average enrichment of the vapour leaving the plate will be given by the mean ordinate of the area enclosed between the curves O-Y_w and O-B, the latter representing the segment of the vapour-liquid equilibrium curve, the ordinate Y_wB, and the point O.

The above procedure indicated for variable vapour composition may be adopted with appropriate modifications for the case of finite local efficiency. This has been done and represented in Fig. 9 for one and three partitions. The average vapour compositions in the two compartments for a single partition have been graphically determined as Y_2^1 and Y_2^2. The subsequent procedure will not be indicated, as it is evident from the figure. The composition of the vapour averaged in each of the four compartments, for the latter case, will be represented by Y_4^1, Y_4^2, Y_4^3 and Y_4^4. The slopes of the two process lines will be $(-2L/V)$ and $(-4L/V)$. For the case of infinite partitions the operating point will be P and the average enrichment of the vapour will be given by the mean ordinate corresponding to an area enclosed between the curves MP and SS and the ordinates P and M.

Application of the Method for Column Design

The computation of the actual number of plates in a distillation column based on the method of partition analysis is based on the following assumptions:

(1) The equilibrium relationship for the system is available. The operating conditions are fixed and therefore the operating lines for the rectifying and stripping sections are available.
(2) A finite local efficiency will be operative on all the plates in the column, although variation in its magnitude from plate to plate may be taken care of.
(3) The partition equivalent of the plate is known under the conditions of operation of the column.
(4) The vapour discharged from plate to plate will be assumed to be of uniform composition which will be equal to the mixed mean value of the compositions of the vapour discharged from each compartment.
(5) The principle of constant molal vaporization and reflux will be assumed.

There are two ways of going ahead of the design procedure. One of them is to start from the top of the fractionating column and the other to start off from the reboiler. The latter method will be chosen first as it is found to be more convenient, due to the fact that the reboiler represents an ideal plate.

Procedure Starting from Reboiler

The graphical design procedure starting from the reboiler is indicated in Fig. 10. The equilibrium streams leaving the reboiler are represented by the point (Y_w, X_w). All the actual plates above the reboiler are assumed equivalent to "two-partition plates". The graphical procedure will be first

Fig. 7. Average composition of vapour leaving partitioned tray as function of local efficiency and number of partitions.

Fig. 8. Equilibrium streams in partitioned tray for non-uniform vapour composition.

Fig. 9. Non-equilibrium stream in partitioned tray for non-uniform vapour composition. Partitions: 1 and 3. Local efficiency: 0.7.

Fig. 10. Graphical design of fractionating column, from reboiler upwards. Partitions: 2. Local efficiency: 0.7 and 1.0.

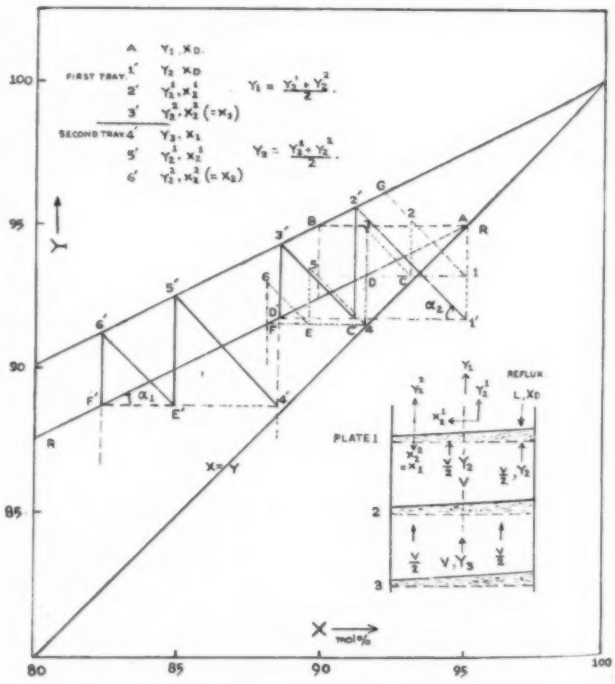
indicated for equilibrium contact, corresponding to 100 per cent local efficiency, and then for finite contact, corresponding to 70 per cent local efficiency. The former procedure will be indicated by full lines and the latter by dashed lines.

The operating line for the stripping section is drawn with a slope equal to 1.5. Point 1 on the operating line indicates the composition of the two streams, (Y_w, X_1) flowing between the reboiler and the first plate. This point is easily fixed because of the fact that the reboiler represents an ideal plate, and is obtained by drawing a horizontal through (Y_w, X_w) to intersect the operating line at 1. In order to determine the composition of the vapour leaving the first plate and that of the reflux flowing down from the second plate, the following construction may be followed. From 1 draw a vertical to intersect the equilibrium curve at 2. In as much as a two-partition plate gives rise to three compartments, point 2 represents the compositions of the equilibrium streams leaving the third compartment, X_2^3 (X_1) being the composition of the liquid flowing towards the reboiler and Y_2 the composition of the vapour discharged from the third compartment. In order to determine the composition of the equilibrium streams in the other two compartments, a straight line of slope equal to $(-3L/V)$ is drawn from 2′ to intersect the horizontal through L at C. A vertical is again drawn from C to intersect the equilibrium curve at 3′, representing equilibrium streams leaving the second compartment. The earlier procedure is repeated to locate D on the horizontal and then 4′ on the equilibrium curve, representing equilibrium streams leaving the first compartment. Another line drawn with a slope equal to $(-3L/V)$ from 4′ intersects the horizontal at A', which represents the composition of the two fluid streams (Y_w, X_2) about to react with each other in the first compartment of the first plate. A' may be recognized as the operating point indicated in the earlier procedure dealing with the development of partition analysis. In the case of application, the process is reversed. The average composition of the vapour leaving the first plate will be given by averaging the ordinates of points 2′, 3′ and 4′. This mean ordinate Y_1 and the liquid reflux flowing from the second plate, X_2, must lie on the operating line. This is easily verified, by noting the co-ordinates of the point 5′, obtained in this graphical procedure, thereby bearing out the validity of the method. The same procedure will now be repeated, commencing from the second reference point, 5′, for locating B' (Y_1, X_3). The location of this point along with the mean ordinate value corresponding to equilibrium streams in the second tray, represented by 6′, 7′ and 8′, locates the point 9′ exactly on the operating line. This corresponds to the second tray. This procedure may be continued till compositions corresponding to feed conditions are reached. From this point onwards the slopes of the process lines will be dictated by the slope of the operating line for the rectifying section.

Procedure for Finite Local Efficiency

A similar treatment will now be attempted for the case of finite local efficiency. The origin will be again point 1. In as much as the material balance considerations fix the value of X_1, in this case also a perpendicular will be drawn from point 1 to terminate at some intermediate point 2 indicating that the liquid stream of composition X_2 delivered from the third compartment of the first tray towards the reboiler is not the outcome of equilibrium contact in the compartment between the vapour delivered from the reboiler and the liquid from the second compartment. The point 2 has to be located by trial and error, because, as will be evident from partition analysis, presented earlier, it is the ratio of the inclined segments from operating points drawn with appropriate slope and terminated at some point and the equilibrium curve that determines the local efficiency. Location of point 2 by considering the ratio (12/12′) as equal to 0.7, the magnitude of the local efficiency, will not be correct. From the point 2 a straight line is drawn with a slope equal to $(-3L/V)$ to intersect the horizontal through 1 at C'. A perpendicular drawn from C' terminates at some intermediate point before intersecting the equilibrium curve, at point 3 which locates the composition of the non-equilibrium streams leaving the second compartment of the partitioned plate. Repeating the earlier procedure, 4 is located giving the composition of the streams leaving the first compartment. Point A is located from 4 by drawing an inclined line of slope equal to $(-3L/V)$, indicating the composition of the liquid stream flowing on to the first tray from the second. The composition of the vapour leaving the first plate will be given by the mean ordinate corresponding to points 2, 3 and 4. This average composition of the vapour taken in conjunction with that of the liquid at point A verifies the material balance consideration, through the point 5 which exactly lies on the operating line. To calculate the composition of the streams on the second plate, the operating point will be 5. By drawing a vertical terminating at point 6, points 7 and 8 are successively located, representing the fluid streams leaving the three imaginary compartments of the second plate. The final location of B determines the composition of the reflux discharging from the third plate to the second and a vertical drawn from this point meets the horizontal corresponding to the average value of the vapour leaving the second plate at a point 9 on the operating line, verifying, in an impressive manner, the applicability of the graphical design procedure based on the partition analysis of a distillation plate. The above procedure may be continued till the feed point is reached. From here onwards the basic procedure will remain the same with the process lines, however, taking on different slopes corresponding to the slope of the operating line and the number of imaginary partitions that the plate in the rectifying section is assumed equivalent to.

Graphical design of fractionating column, from condenser downwards. Partition: 1. *Local efficiency:* 0.7 *and* 1.0.



From inspection of Fig. 10, it is evident that, to enrich the vapour from Y_w equal to approximately 11 mol per cent to about 35 mol per cent corresponding to point 9′, exactly two ideal plates of partition equivalent to 2 and 100 per cent local efficiency will be required. The number of theoretical plates, defined according to current practice, required to bring about the same enrichment will be approximately three, whereas a partitioned plate with approximately 70 per cent local efficiency will require only a slight excess over three plates. Since an increase in the number of imaginary partitions will correspond to an increase in the extent of lateral mixing, a distillation column consisting of plates of different design with partition equivalent greater than two will need a smaller number of plates under identical conditions of operation.

Calculating Number of Plates Starting from Column Top

The design procedure for the calculation of actual number of plates starting from the top of the distillation column will now be presented. The sketch at the foot of Fig. 11 indicates the composition of the streams on the top three plates of the fractionating column. A product composition of 95 mol per cent will be assumed (Y_1, X_d). A reflux ratio of unity fixes the point A on the diagonal R-R and also on the line $X = Y$. A partition equivalent of one will be assumed for the plate, giving rise to two imaginary compartments. The graphical procedure will first be indicated for equilibrium contact and then for a local efficiency of 0.7. The problem posed now is: given the composition of the vapour leaving the first plate (Y_1) and going to a total condenser to be cooled to the bubble point and that of the liquid reflux (X_d) delivered to the same plate, to compute the composition of the liquid leaving the first tray (X_1) and that of the vapour discharged from the lower plate, 2 (Y_2). The problem reduces to the calculation of a second point on the operating line given the initial point A.

On a vertical from A drawn downwards, locate by trial and error 1′ such that, considering it as an operating point, a straight line drawn with a slope equal to $(-2L/V)$ will locate first 2′ and then, repeating the procedure, 3′ on the equilibrium curve, 2′ and 3′ represent the composition of the fluid streams leaving the two compartments. The correctness of location of 1′ is verified by the fact that the horizontal through 1′ and the vertical from 3′ intersect at D' on the operating line. Moreover, the average vapour composition given by the mean ordinates of 2′ and 3′ corresponds to point A. Again drop a perpendicular and locate, by trial and error, 4′. Proceed as before and locate points 5′ and 6′ on the equilibrium curve representing compositions of the fluid streams leaving the two compartments. The correctness of the point 4′ is verified again by the fact that a horizontal through and a vertical through 6′ intersect at F' on the operating line. Further, the average composition of the vapour leaving the second plate given by the mean ordinate of 5′ and 6′ corresponds to D'. This procedure may be repeated till the feed composition is reached. The continuation of the graphical procedure in the stripping section will depend on the material balance effective in that section, which will appropriately change the slope of the process lines.

Method for a Given Finite Local Efficiency

The procedure for finite local efficiency of 0.7 will now be indicated. The starting procedure will be the same as for equilibrium contact. Locate 1 instead of 1′ on a vertical from A such that a straight line drawn with a slope equal to $(-2L/V)$ will terminate at some intermediate point 2 and projected will intersect the equilibrium curve at G. Point 2 is located such that the ratio $(1 - 2/1 - G)$ equals 0.7. On a vertical from 2, locate C on the horizontal through 1. Draw again a line with slope equal to $(-2L/V)$, locating 3 at some intermediate point. A perpendicular dropped from 3 will intersect the horizontal through 1 at D on the operating line, indicating the correctness of location of point 1. D represents the composition of the vapour leaving the second plate and the liquid leaving the first. The graphical procedure is repeated to locate points 4, 5 and 6 such that the perpendicular from 6 intersects the horizontal through 4 at F on the operating line. The graphical procedure will terminate at the feed composition being reached and will be modified for the stripping section.

Conclusion

The merit of the new method, outlined in this paper, lies in the fact that the effect of longitudinal mixing that tends to introduce concentration gradients in the liquid and vapour can be duly accounted for in the partition equivalent of the actual plate, a characteristic that is capable of evaluation by simple experimental procedure. Further, the effect of local plate efficiency and the ratio of molar vapour and liquid rates on the stepwise procedure is allowed for in the variable slope of the process lines and the termination of such lines at some intermediate stage corresponding to a particular local efficiency. Further, the method does not assume linearity of the vapour-liquid relationship.

In conclusion, it may be remarked that the improved method of partition analysis that has been presented in this article is based on the important assumption that the partition equivalent of an actual plate, that represents the departure of the plate from ideal behaviour, is capable of experimental evaluation. It may be that the partition equivalent is a function of the vapour and liquid rates, but it is probable that it will be mainly a function of the mechanical design of the plate. This characterization will constitute an important piece of investigation and will form the basis of the graphical design procedure developed here.

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Superphosphate Manufacturers' Conference

THE International Superphosphate Manufacturers' Association (I.S.M.A.) will hold its biennial Technical Conference in Wiesbaden from 11 to 15 September, 1961. A record number of some 170 delegates from 22 countries is expected to attend. Twenty-one papers will be presented, dealing with both straight and compound (N-P-K) fertilizers, the production and uses of sulphuric, phosphoric and hydrochloric acids for the fertilizer industry, the recovery of by-products, and various other aspects. In addition, delegates will be able to exchange views in informal discussion groups on three current topics of interest: the production of liquid fertilizers, the standardization of methods of fertilizer analysis, and techniques of granulation.

Dr. B. Raistrick (United Kingdom), chairman of the I.S.M.A. Technical Committee, will preside over the Conference.

A MODIFIED CONVERTER FOR SULPHURIC ACID MANUFACTURE

JUDGING from a recent article by the Rumanian engineer I. SAMOIL,[1] there is considerable interest in Rumania in methods of increasing the output of sulphuric acid from existing plants. SAMOIL notes that in the last five years the output of sulphuric acid has increased 2.4 fold, and that in 1960 about 25 per cent of the total production of sulphuric acid was achieved by increasing the capacity of existing plants.

He then described how the output from a contact plant was increased by modifying the converters, their relevant data being as follows:

Internal diameter	3800 mm
Total height	9059 mm
Number of catalyst layers	5
Total quantity of catalyst	15,000 l
Total height of the layers	1425 mm
External heat exchangers	3
Rated production capacity	50 tons H_2SO_4/day
Ratio of H_2SO_4/catalyst per 24 h ...	5.7 tons/ton.

The method of filling and assembling the original and modified converters is shown in Figs. 1 and 2.

In the converters the path of the gases is the following: the sulphurous gases containing approx. 5 per cent SO_2 (the optimum working concentration for this type of reactor), pressure fed by a blower, pass consecutively through the heat exchangers S I, S II and S III (Fig. 2) and reach a temperature of 440°C. They enter the upper part of the contact oven, above the first layer of catalyst, at this temperature, pass through the first layer and reach a temperature of 550-580°C as a result of the exothermic oxidation reaction of SO_2 to SO_3.

Through four perforated tubes mounted between layers 1 and 2 cold sulphurous gases are forced in in order to reduce the temperature at the entrance to layer 2 to about 500°C. In passing through layer 2, the gases react, and are heated to 540-580°C.

An 85-87 per cent conversion is obtained in the first two layers.

Between the layers 2 and 3 there is a dividing wall; the hot gases are directed through a pipe into the heat exchanger S III, through which they pass countercurrent to the sulphurous gases, thereby giving up some of their heat and cooling down to 440-450°C; at this temperature they re-enter the converter above the third layer of catalyst.

In passing through layer 3, the gases continue to react and reach a temperature of 480°C. In order to be again cooled down to the optimum temperature of approx. 440°C, the gases which have passed through layer 3 are directed towards the converter walls by means of a cast-iron deflecting plate, mounted under the grate of layer 3, and by sheet steel aprons. The wall of the converter at these points is double and cooled on the outside with air from a blower. On coming in contact with the walls, the gases are cooled and are then returned to the centre of the converter above layer 4 with the aid of cast-iron deflecting plates.

After having passed through layer 4, the gases are directed in the same manner to the cooled walls of the converter. They then pass through layer 5 and are then again directed to the periphery by the deflecting plates located under layer 5—they then enter (at a temperature of 440-445°C) the heat exchangers S II and S I via a gas pipe. They pass through the heat exchangers countercurrent to sulphurous gases which are on their way to the converter, and are cooled down in the process to a temperature of approx. 220°C, at which temperature the oxidized gases leave the converter and pass into the absorption unit.

A number of auxiliary pipes permit the introduction of cold gases at various points of the flow path in order to maintain operating conditions at their optimum values.

The theoretical yield is 97 per cent for a 5 per cent SO_2

gas at a rate of flow of 10,000 N m^3/hr, which corresponds to 50 tons H_2SO_4/day.

The converters were commissioned in March-April 1957 and functioned without interruption until March-April 1960. In general, the production of 50 tons of sulphuric acid monohydrate per day per oven has been realized with yields between 93 and 96 per cent, and occasionally yields of 97 per cent have been obtained.

The operating conditions for one of the converters at various periods are represented in Table 1.

In 1958, when a Freeman-Nichols type mechanical roasting oven was converted into a fluidized-bed roasting oven for pyrites, the roasting capacity increased, which presented the problem of increasing the total production capacity of the section. It was observed that in some phases of the manufacturing process—dry purification, wet purification, drying and absorption of the gases—it was possible to increase the production capacity by relatively inexpensive modifications. As regards increasing the capacity for oxidizing SO_2, the general opinion was that this could only be achieved by constructing a new contact unit with all the necessary auxiliary equipment: blower, heat exchanger, cooler for sulphuric anhydride, etc. This, however, would have entailed a large investment, the importing of certain materials and specialized equipment, a delay in putting the plant into operation, and there was the possibility of teething troubles to be faced. With all these factors in view, SAMOIL and his co-workers carried out a theoretical study on the possibility of increasing the capacity of the existing converters by increasing the charge of catalyst and by modifying the design in such a way as to ensure optimum operating conditions. Naturally enough, the pursuit of this investigation met with some difficulties, since in Rumania no one was experienced in converter design and calculation.

Charging a Converter with Additional Catalyst

The converter was charged with 15,000 l, i.e., 8700 kg, of vanadium pentoxide catalyst corresponding to 5.7 t of H_2SO_4 monohydrate/t of catalyst in 24 hr.

The catalyst was arranged in 5 layers (Fig. 1), and details of the height and quantity of catalyst on each bed are given in Table 2.

From an analysis of the available space over each layer, and taking into account all the factors which influence converter performance, uniform distribution of catalyst in a bed, free flow of the gases, contact time, etc., SAMOIL concluded that a further quantity of 6660 l. of catalyst could be charged into the contact oven, distributed over the layers as shown in Table 3.

Examining a few parameters before and after the additional catalyst charge and comparing them with the data given by MALIN,[2] it follows that as far as the diameter of the contact oven—3.8 m—and the resistance to flow before modification—approx. 20 mm Hg—and after modification —approx. 50 mm Hg—are concerned, these values are within the limits given by MALIN (page 446 of reference 1), which indicates that a contact mass of 118 l. is required with a gas of 5 per cent SO_2 per ton of H_2SO_4, in 24 hr, for a degree of conversion of 97 per cent; for a 6 per cent SO_2 gas the mass of catalyst is 149.5 l. and for a 7 per cent SO_2 gas it is 198 l. (page 446, Table 55). In the case investigated by SAMOIL the amount of catalyst specified before modification was 300 l. and after modification 288.8 l. of catalyst per ton H_2SO_4 produced in 24 hr.

Table 4 gives the apparent and the real velocity of the gases before and after modification.

In the calculation of the data given above, it was considered that the rate of flow of gases before modification was 10,000 N m^3/hr for a production of 50 tons H_2SO_4 per day, and that after modification it would be 15,000 N m^3/hr for a production of 75 tons H_2SO_4/day. It was also

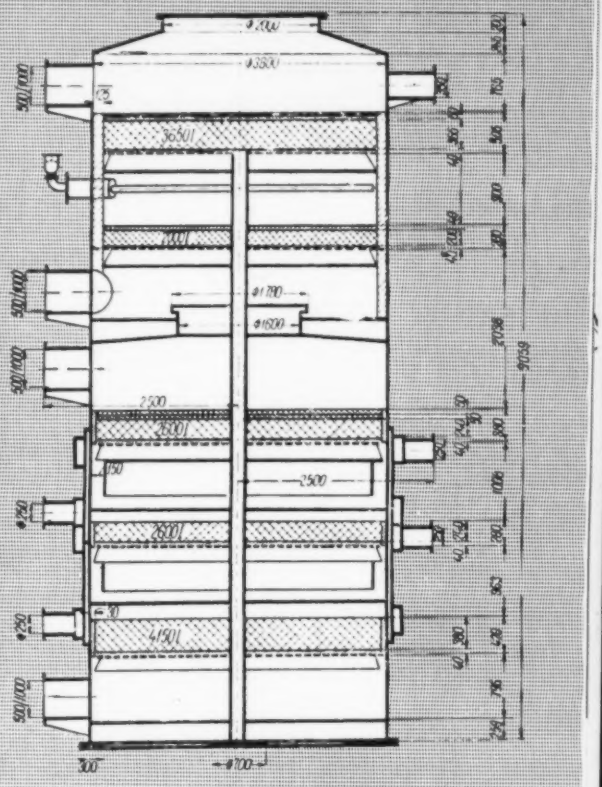


Fig. 1. Details of catalyst charge in a 50 t capacity converter.

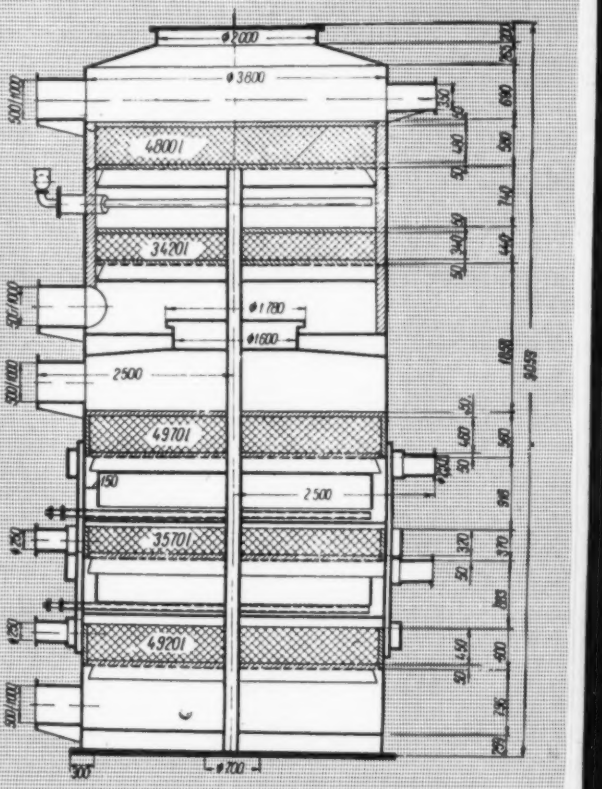


Fig. 2. Layout of 50 t capacity converter.

Table I

Date	Rate of Flow of Gas m^3/h	SO_2, %	Yield %	Production H_2SO_4 Tons	Temperature °C						
					Layer 1	Layer 2		Layer 3		Layer 4	Layer 5
					Inlet	Inlet	Inlet	Inlet	Outlet	Outlet	Outlet
27.5.57	—	3.55–5.90	94.6–95.3	40	475–495	560–580	560–575	425–445	425–455	415–445	400–420
10.3.58	10,000	5.37–5.99	93.0–94.8	50	445–450	560–565	565–570	430	445	440–450	430–435
10.3.59	9,500	5.44–6.51	93.0–94.0	55	445–450	575–595	580–600	430–445	470–485	460–480	430–445
1.2.60	9,500	5.90–6.72	93.4–94.5	58	460–480	590–605	615–620	470–495	470–495	470–490	410–435

taken into account that the temperature in layers 1 and 2 is about 550°C and in layers 3, 4 and 5 it is 440°C. The velocities of gases for the modified converter are similarly within the limits given by MALIN (page 458, reference 2).

Table 5 gives the apparent and real times of contact in the two cases; it may be seen that the times of contact with the layers differ a little, but the total time of contact has not changed.

The time of contact necessary to achieve a 97 per cent conversion in five stages may be calculated with the aid of the diagrams given by MALIN (pages 432-3 and Table 57, page 466, reference 2).

Stage 1—per cent conversion from 0-75 per cent requires 0.35 sec.

Stage 2—per cent conversion from 75-88 per cent requires 0.15 sec.

Stage 3—per cent conversion from 88-94 per cent requires 0.15 sec.

Stage 4—per cent conversion from 94-95.5 per cent requires 0.15 sec.

Table II

Layer No.	Height mm	Quantity	
		l	kg
1	365	3650	2117
2	200	2000	1160
3	240	2600	1508
4	240	2600	1508
5	380	4150	2407
Total	1425	15,000	8700

Stage 5—per cent conversion from 95.5-97 per cent requires 0.20 sec.

Total—for a per centage conversion from 0-97 per cent the time of contact required is 1.00 sec.

Since the actual contact time after modification was 2.00 sec, this provided a safety factor of 200 per cent.

Charging the contact oven with additional catalyst may therefore lead to good results as long as the optimum temperatures are ensured; the achievement is described below along with some modifications carried out on the converter itself in order to improve its operation. A part of these modifications was considered necessary when certain constructional defects were discovered after the contact oven had been taken out of service and emptied of its contents.

Improvement of Temperature Control

In order to obtain good yields, it is necessary to maintain optimal temperatures at the inlet and outlet of each layer of catalyst. It was found that the temperature at the outlet from layer 1 could not be controlled because the thermocouple was mounted underneath the cooling gas tubes and thus only indicated the temperature at the inlet to layer 2. Therefore, a thermocouple was placed at the outlet of the gases from layer 1, above the cooling gas tubes. Between layers 3 and 4 there was a thermocouple which was located at the outlet of the gases from 3, while at the inlet to layer 4—after cooling—the temperature was not known because there was no thermocouple to indicate it. Since it is known that the temperature at the inlet

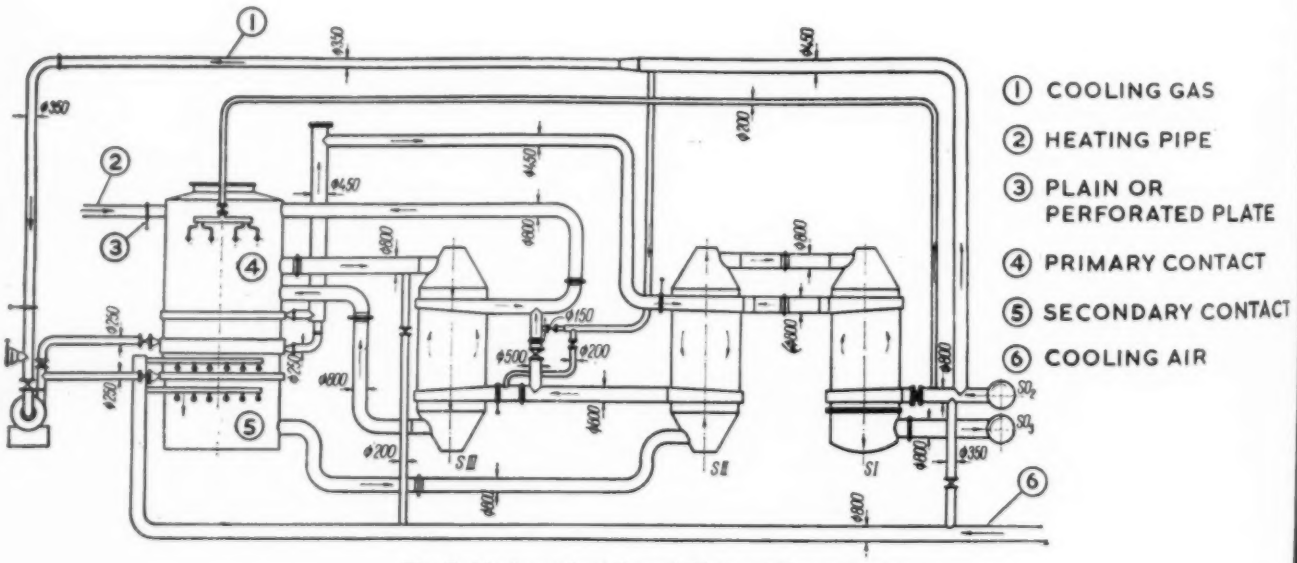


Fig. 7. Horizontal section of 75 t capacity converter.

Table III

Layer No.	Height mm	Quantity		Additional Charge	
		l	kg	l	kg
1	480	4800	2784	1150	667
2	340	3400	1972	1400	812
3	460	4970	2882	2370	1374
4	320	3570	2070	970	562
5	450	4920	2854	770	447
Total	2025	21,660	12,562	6660	3862

to a layer determines the optimum operating conditions of the layer, it was decided to place two thermocouples at the gas inlet to layer 4, one at the centre and one at the edge. The situation between layers 4 and 5 being the same, it was decided to install two thermocouples here also. In this way it is possible to follow the operation of each layer of catalyst quite well and to take whatever measures are necessary to ensure the best operating conditions.

The Cooling of Gases after Layer 1

The oxidation of sulphur dioxide to sulphur trioxide takes place with the evolution of considerable heat, according to the equation

$$SO_2 + \tfrac{1}{2} O_2 = SO_3 + 22{,}600 \text{ cals.}$$

By increasing the rate of flow of the gases from 10,000 N m^3/hr to 15,000 N m^3/hr, the amount of SO_2 oxidized also increases, as follows:

$$5000 \times 5/100 = 250 \text{ m}^3/\text{hr} = 725 \text{ kg/hr.}$$

Considering that the conversion in the first layer is 73 per cent, the additional amount of heat liberated will be

$$725 \times 73/100 \times 22{,}600/64 = 186{,}891 \text{ kcals.}$$

Because of this heat evolved, the temperature of the gases rises to approx. 580°C; they must be cooled to approx. 500°C before being allowed to enter layer 2. For this purpose four perforated tubes are mounted between layers 1 and 2 to enable cold gases to be introduced in the required amounts (Fig. 1). In order to provide the increased requirement of cold gases to deal with the increased amount of heat evolved, it was proposed to double the number of holes in each tube.

Cooling of Gases after Layer 3

The gases leave layer 2 at a temperature of 540-580°C and must be cooled to 440-450°C before being allowed to enter layer 3. For this purpose they are directed into an external heat exchanger (Fig. 2, S III) which they traverse in countercurrent with the fresh gases which are on their way to the first layer of the contact oven, and to which gases they give up some of their heat. The surplus of heat obtained after layer 2 through increasing the flow of gases is thus seen to be utilized in heating the excess gas entering the contact vessel.

Since objections were raised to the effect that the cooling surface of the pipes in the heat exchanger would be too small to ensure the cooling of the increased gas quantities to 440°C, it was proposed that a connecting pipe be fitted between the main air pipe and the gas pipe which connects layer 2 to the heat exchanger S III (Fig. 3). Through this pipe it is possible to introduce cold air into the circuit and thereby cool the gas to the desired temperature. This method of cooling was used only when it was impossible to achieve the necessary cooling by means of the heat exchanger.

Gas Redistribution over the Third and Fourth Layers

When the converter was emptied it was observed that the layers 3, 4 and 5 had inclined edges. This was attributed to non-uniform circulation of the gases in the vicinity of

Table IV—Speed of the Gases

Layer No.	Apparent velocity		Real velocity n/s	
	Before modification	After modification	Before modification	After modification
1	0.24	0.36	0.72	1.08
2	0.24	0.36	0.72	1.08
3	0.25	0.37	0.65	0.98
4	0.25	0.37	0.65	0.98
5	0.25	0.37	0.65	0.98

Table V—Contact Time in sec.

Layer No.	Before modification	After modification	Before modification	After modification
1	1.52	1.33	0.50	0.44
2	0.83	0.94	0.27	0.31
3	0.96	1.24	0.37	0.47
4	0.96	0.86	0.37	0.32
5	1.52	1.21	0.58	0.46
Total	5.79	5.56	2.09	2.00

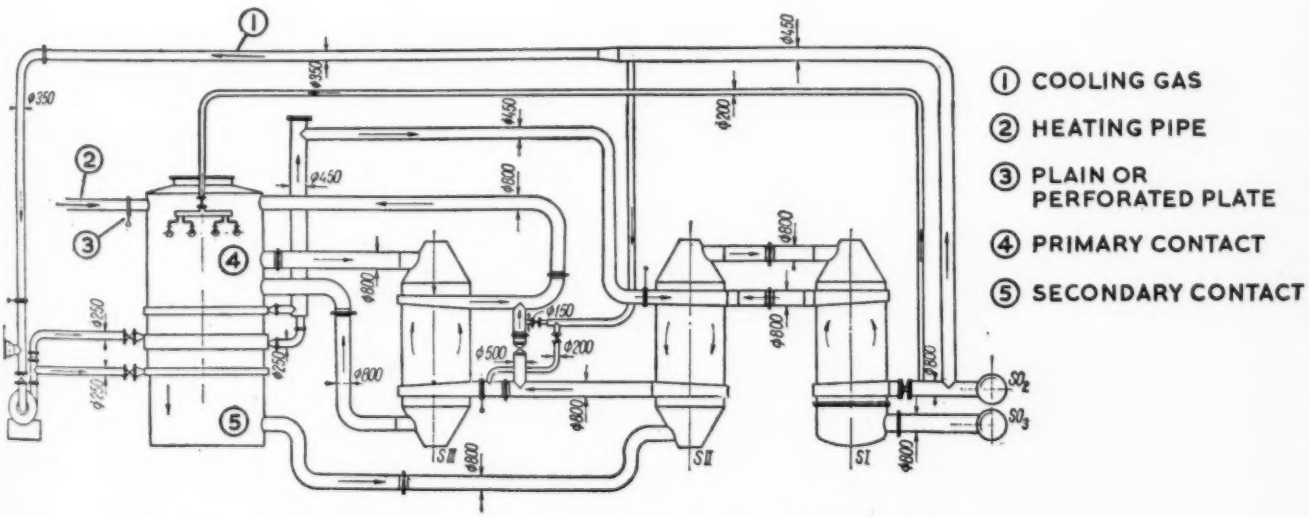


Fig. 6. Details of catalyst charge in a 75 t capacity converter.

Table VI

	Rate of Flow of Gas m³/h	SO_3 %	Yield %	Production H_2SO_4 Tons	Temperature °C									
					Layer 1		Layer 2		Layer 3		Layer 4		Layer 5	
					Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
6.4.60	11.800	5.1–6.97	94.4–96.8	80										
7.4.60	11,000	5.9–7.1	95.4–97.0	81										
10.4.60	12,500	5.6–6.2	96.3–97.3	76										
11.4.60	12,000	5.2–7.4	96.1–97.1	76										
25.4.60	12,500	4.6–6.2	96.7–97.6	65										
26.4.60	12,700	5.4–6.4	95.2–97.3	74	458	560	560	580	455	465	445	455	440	435
27.4.60	12,700	5.3–6.6	95.7–97.6	75										

these layers. Because of the cast-iron plates used to direct the mass to the cooler parts of the vessel, the gases—which have a tendency to take the shortest path—gravitate to the edges, at the peripheral zone of the converter, where the mass became inclined and where part of the catalyst had passed through the grating. The formation of bevelled edges created points of lower resistance, which accentuated the non-uniform circulation of the gases.

In order to eliminate this deficiency it was proposed to drill holes into the cast-iron deflecting plates; the size of the holes was calculated to allow approx. 30-40 per cent of the gases to pass through them and to circulate through the central section of the converter, leaving 60-70 per cent of the gases to circulate through the peripheral section of the converter. Fig. 4 represents one of the original deflecting plates and Fig. 5 one with holes drilled into it.

Gas Cooling between Layers 3-4 and 4-5

After two years' operation, the temperature of the gases in layers 4 and 5 exceeded the optimum temperature, air cooling of the outer jacket being no longer sufficient, particularly for gases with more than 6 per cent SO_2. This was explained by the presence, upon the air-cooled part of the unprotected metal jacket, of layers of rust and corrosion products which formed an insulating layer. Since this was likely to recur it was proposed to mount a bundle of six cooling tubes between the layers 3-4 and 4-5. These tubes would also serve to cool the gases circulating in the central part of the converter. The tubes have a diameter of 100 mm and pass through the jacket at a single point, the head in the interior of the oven being sealed off. In the interior of the tube of 100 mm dia. another tube of 50 mm dia. is introduced. The cold air is passed through the 50-mm-dia. tube and leaves through the 100-mm tube and cools the gases. The mounting of these tubes is shown in Figs. 6 and 7. It is recommended that they should be made of alloy steel (V2A) so as not to corrode.

Uniform Gas Redistribution over the Fifth Layer

According to the design, the cast-iron plates were mounted under layer 5 in the same way as under layers 3 and 4, so as to direct the gases which have passed through layer 5 to the converter outer jacket. Since these gases are no longer cooled in the converter, directing the stream of gas to the outer mantle is to be avoided, since it causes poor circulation. In order to prevent this from happening, SAMOIL discarded part of the cast-iron deflecting plates, and instead of eight plates, he made use of three only, which were mounted in front of the gas outlet.

The converters were modified in March-April 1960, and the results have given satisfaction. Table 6 summarizes the performance achieved after modification. It will be seen that gases with a concentration of SO_2 up to 7 per cent have been used at flow rates in excess of 12,000 m³/hr per oven; optimum temperatures have been attained in each layer; constant yields between 96 and 97 per cent have been obtained; 80 tons of sulphuric acid monohydrate were produced per day, the production capacity being increased by more than 50 per cent. Later, even better results were obtained—up to 90 tons/day per oven—while maintaining the other parameters.

In conclusion, it may be said that by charging the contact ovens with additional quantities of catalyst, and by carrying out a number of modifications, it has been possible to increase the production capacity by 60-70 per cent with a consequent marked saving in investment.

REFERENCES
[1] SAMOIL, I. *Revista de Chemie*, 1961, **12** (2), 65.
[2] MALIN, "Technology of Sulphuric Acid", *Gos. Khim.*, 1956.

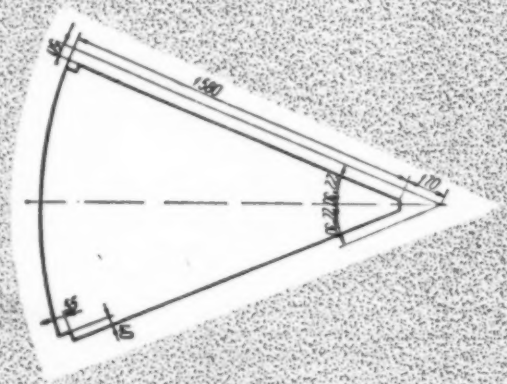


Fig. 3. Connections of a 75 t converter.

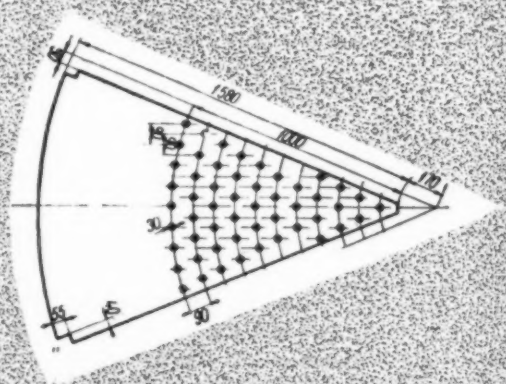


Fig. 4. Deflecting plate for 50 t converter.

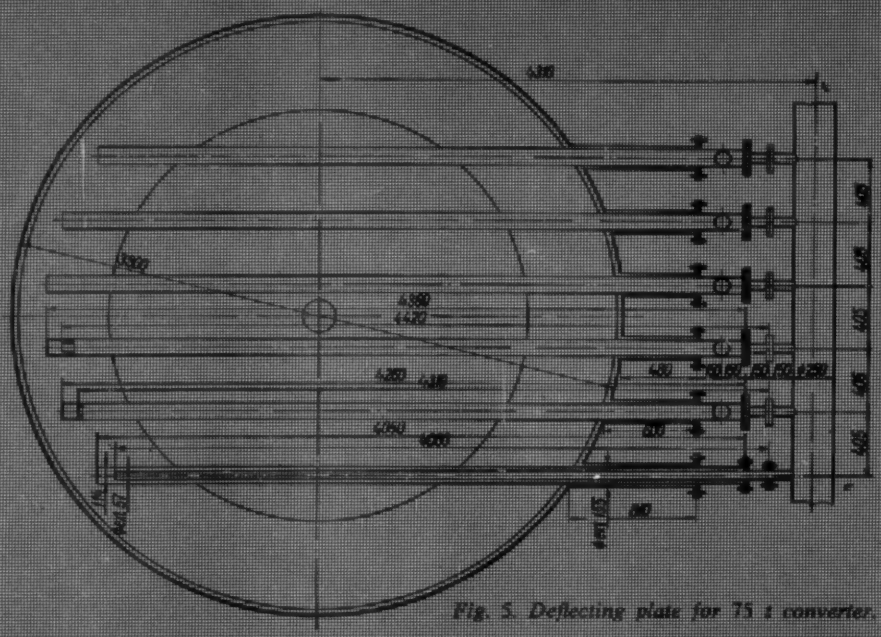


Fig. 5. Deflecting plate for 75 t converter.

Come-back for Lead Linings?

ACCORDING to "News and Progress in Metals", prepared in the United States by W. Alec Jordan Associates to cover ideas and developments in the fields served by the American Smelting & Refining Co., a spectacular come-back for lead linings in chemical process equipment can be expected. Because the industry failed to develop new fabricating techniques, lead temporarily lost its pre-eminence as a corrosion-resistant lining to newer and more aggressively marketed materials such as plastics, glass and ceramics. One of the reasons often quoted for adopting other materials was the high cost of hard-to-find lead burners for maintenance.

Substantial progress is now claimed to have been made in lead technology and new lead-lined equipment can be expected to endure for years without maintenance. Many manufacturers of lead-lined process equipment in the United States now provide maintenance service, under contract, even after years of use and, using recently developed techniques, repairs can be effected in a matter of hours by ordinary maintenance men.

Lead-lined equipment is claimed to be usually lower in cost and less sensitive to thermal and physical shock than glass and ceramics, while plastics tend to change character over long periods of constant use. Lead can also be recovered at the end of a useful life for close to its original cost.

One of the recent technical developments in the United States in the field of lead linings is a series of composite metals by Knapp Mills Inc. consisting of a metallurgically bonded lead surface of unrestricted thickness applied to one or more of a wide range of base metals, such as Cupralum (copper/lead), Bauxilum (aluminium/lead), Ferroblum (carbon steel/lead) and Nicrolum (stainless steel/lead). The advantages claimed for these composite metals are lower initial cost than stainless steel, glass or ceramic-lined equipment, nickel or copper alloys or high silicon iron; installation costs less than or equal to competitive materials; and simple maintenance techniques. Because the materials are metallurgically bonded, corrosives cannot penetrate between the metals. If a leak should occur, it penetrates directly through to the outside surface and may be repaired from the equipment exterior, if necessary. It is also claimed that repairs can be carried out by simple techniques, even in the vertical position, and that, after use for a period of years, vessels can be reconditioned by flame cleaning and the lead surface even thickened if necessary.

Stiffened by other metals, the lead cladding provides a good nuclear gamma shield while the metallurgical bond yields efficient heat transfer, making these so-called Insmetals useful materials for the nuclear and allied industries.

Industrial equipment currently being made from these metals include colour anodizing tanks operating at 300°F (Ferrolum with Cupralum heating coils); chlorine dioxide generators for the pulp and paper industry operating at 180°F (Ferrolum); fractionating columns for urea synthesis operating at 380°F, 3000 psi (Ferrolum); 4090-gallon tank cars for the rail transportation of bromine under conditions involving constant vibration and repeated shock (Ferrolum); heating and cooling coils for corrosive liquids operating under conditions frequently involving high temperatures and pressures and corrosive conditions both inside and outside the coil (Ferrolum, Cupralum and Nicrolum); shipping casks for the transportation of spent nuclear fuel rods for reprocessing, the operating hazards of which include vibration, shock, high heat output, corrosive materials and extreme gamma radiation (Nicrolum and Ferrolum with Cupralum cooling coils).

BRITAIN'S FIRST LURGI PRESSURE-GASIFICATION PLANT

General view of the Westfield Works from the north.

THE Westfield works were officially opened on Tuesday, 27 June, by HER MAJESTY THE QUEEN.

The plant, which the Scottish Gas Board are building at a cost at £6.6 million, is the first Lurgi process of high-pressure gasification in Britain.

It is at present producing 15 million cu ft of gas a day, and this output will be doubled when the second stage of construction is completed in a few months' time. Lurgi gas is produced at high pressure and can be distributed over considerable distances. The Scottish Gas Board are therefore constructing a high-pressure pipeline across central Scotland to link with grid systems exising over some 4000 square miles. The estimated total cost of the plant and high-pressure pipeline is £8.5 million.

Raw Material

The Lurgi process uses low-rank, non-coking, open-cast coal, oxygen and steam.

This coal, which is unsuitable for gas-making by conventional methods, is supplied from open-cast workings adjacent to the plant. A contract between the Scottish Gas Board and the National Coal Board provides for adequate supplies of coal for 20 years or during the life of the open-cast workings, whichever is the longer.

The Gasifiers

The Lurgi gasifier is a mild-steel vessel of fusion welded construction about 19 ft high and 10 ft o.d., equipped with a slowly rotating coal distributor. Coal crushed to $\frac{1}{8}$-$1\frac{1}{4}$ in. enters through a lock-hopper at the top, steam and oxygen are introduced at high pressure at the bottom, and gas is generated from the reaction at 30 atm. Each gasifier produces over $7\frac{1}{2}$ million cu ft of gas a day from 240 tons of coke. Three German-made gasifiers are presently installed, two of which are in use at any time.

Steam Plant

The steam-raising plant consists of two boilers which can each produce 45,000 lb of steam/hr at 450 psi. They burn the same open-cast coal crushed to $\frac{1}{8}$ in. and are fired by the "Ignafluid" method developed in France. "Ignafluid" firing is a modern method which operates on a "fluidized fuel bed" principle, and burns very fine low-grade fuels, smokelessly and efficiently.

Fine coal enters at the front and drops on a mechanical grate. A pulsating flow of air from under the grate holds the fuel bed in suspension, where some of the fine particles are burned. The bulk of the coal is eventually deposited—and burned—on the furnace floor at either side of the grate. The semi-molten ash flows to the grate and is carried to the back of the furnace and finally deposited as clinker on the ash conveyor.

Oxygen Plant

The oxygen plant consists of two units of the liquid-pump type and each unit has a capacity of 100 tons a day of 95 per cent pure oxygen. Oxygen is delivered to the gasifier at 400 psi. This is the first time liquid oxygen pumps have been used for the Lurgi gasification process; all other plants have used gaseous oxygen compressors.

Cooling

Crude gas leaves the gasifiers at 400-450°C. Tar-water is sprayed into the gas in a quench cooler and its temperature

is reduced to about 196°C. The gas passes from the waste heat boilers to a pre-cooler, an after-cooler and a final cooler.

Purification

The cooled gas then passes through various stages of purification. Benzole is removed by washing with light oil, and recovered.

Carbon dioxide and hydrogen sulphide are simultaneously removed in a "Benfield plant". CO_2 content of cooled Lurgi gas is about 27 per cent and H_2S content about 0.8 per cent. These are absorbed in a 35 per cent solution of potassium carbonate in two packed towers operating at about 325 psi and 110°C. The K_2CO_3 solution is regenerated by steam stripping at 5 psi and the acid gases then pass to an alumina catalytic conversion plant where H_2S is oxidized to SO_2. Final traces of H_2S are removed in a "Bischoff" system of purification with hydrated iron oxide, and the waste gases are then discharged to the main chimney stack.

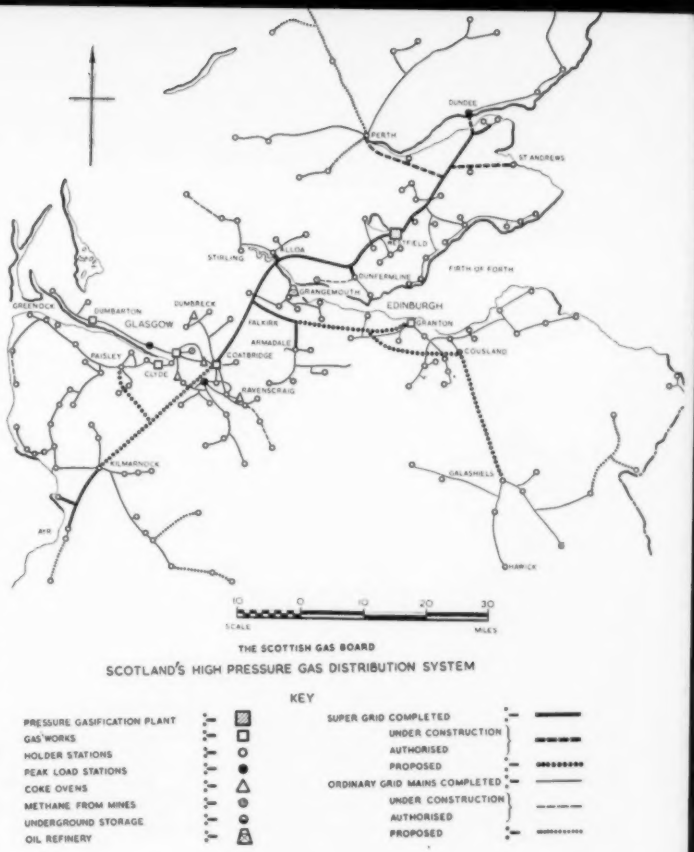
Enrichment

Purified Lurgi gas has a calorific value of 400 Btu/cu ft and its composition is approximately $H_2 = 50$ per cent, $CO = 25$ per cent, $CH_4 = 12$ per cent. It is enriched with butane to 450 Btu/cu ft and delivered to the high-pressure pipeline where a maximum pressure of 250 psi is allowed. The design of a suitable butane feed pump presented considerable technical difficulties. The pumps eventually selected were two variable capacity reciprocating pumps of duplex design, provided with a zero leakage gland, capable of handling boiling butane at a steplessly variable feed rate from zero to 950 gal/hr, at −18 to +35°F and up to 317 psig.

Butane and gas are intimately mixed in a highly-baffled short section of 12-in. pipeline.

Future Developments

During the second stage which is now in progress, a fourth Lurgi gasifier manufactured in Britain will be installed, as well as a newly developed raw gas conversion plant to reduce the CO content of the gas to less than 8 per cent. A further "Ignafluid" steam boiler will be added, and a sulphur recovery plant to remove sulphur from the waste gases will also be installed. The main effect of these developments will be that the total production of gas will be doubled to about 30 million cu ft/day.



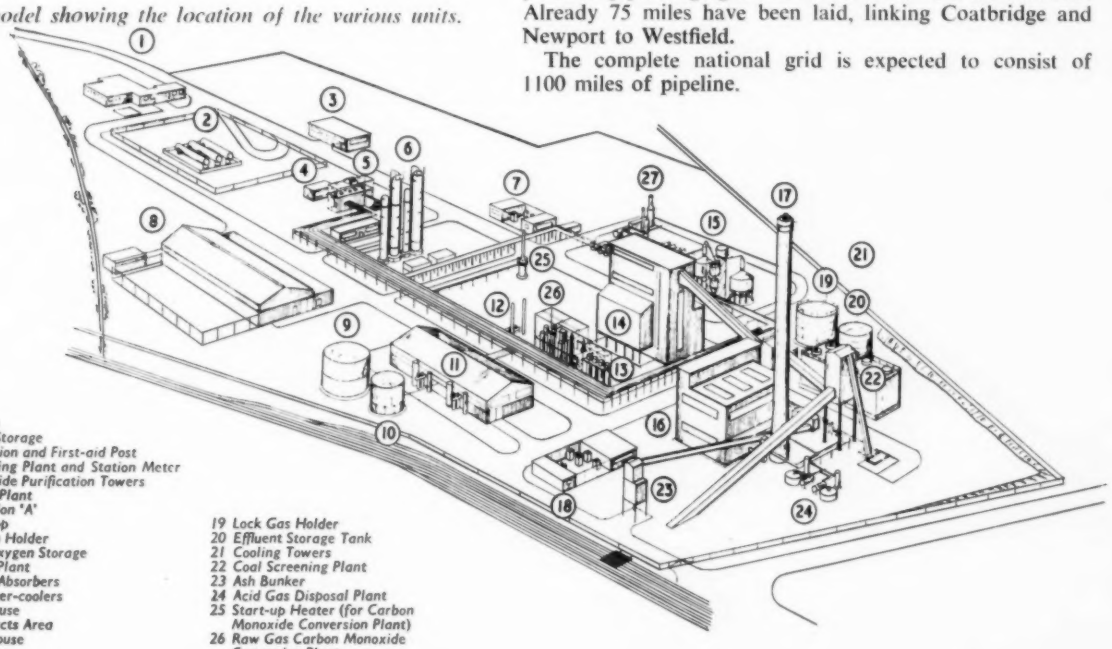
In planning the Westfield works much information was made freely available by those engaged on similar projects in other parts of the world. All the experience gained during the construction and operation of Westfield will be made available to those concerned with the building of other Lurgi plants in the future.

Piping Gas to Consumers

The pipeline for carrying the gas from Westfield to local grid systems round Glasgow in the west and Perth and Dundee in the north is designed for a maximum working pressure of 300 psi. The national supergrid, as at present contemplated, comprises some 260 miles of steel high-pressure pipe ranging in size from 12 in. to 2 in. diameter. Already 75 miles have been laid, linking Coatbridge and Newport to Westfield.

The complete national grid is expected to consist of 1100 miles of pipeline.

A model showing the location of the various units.



1 Canteen
2 Butane Storage
3 Fire Station and First-aid Post
4 Gas Drying Plant and Station Meter
5 Final Oxide Purification Towers
6 Benfield Plant
7 Sub-station 'A'
8 Workshop
9 Nitrogen Holder
10 Liquid Oxygen Storage
11 Oxygen Plant
12 Benzole Absorbers
13 Lurgi After-coolers
14 Lurgi House
15 By-products Area
16 Boiler House
17 Chimney
18 Sub-station 'B'
19 Lock Gas Holder
20 Effluent Storage Tank
21 Cooling Towers
22 Coal Screening Plant
23 Ash Bunker
24 Acid Gas Disposal Plant
25 Start-up Heater (for Carbon Monoxide Conversion Plant)
26 Raw Gas Carbon Monoxide Conversion Plant
27 Ammonia Treatment Plant

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THE FROTH-CONTACT HEAT EXCHANGER

A heat exchanger is described in which the fluid to be cooled is passed through a bank of tubes around which froth is generated by the passage of air upwards through a tray containing water and fitted with a perforated plate. Experiments described show that the heat-transfer coefficient for this type of exchanger has approximately the same value as is obtained in a water-cooled shell-and-tube exchanger. The significance and use of this method of increasing the air-side heat-transfer coefficient in air-cooled installations is discussed and illustrated by worked examples giving the dimensions of froth exchangers for different air conditions

by W. SMITH and A. POLL

IN regions where water is plentiful, air-cooled heat exchangers, although their performance is being progressively improved,[1] are still, both in capital and operating costs, more expensive than water-cooled heat exchangers of the same duty. Even so, air cooling is occasionally used, for the choice is sometimes determined not by economics, but by convenience.

As a cooling medium, air has the obvious advantage over water that it is available in all situations and in any quantity at the site of the exchanger, and the pumping of coolant water from its source to the exchanger is thereby avoided. Also, purification of the air before use or recovery after use, as is sometimes required with water, is unnecessary. Further, water-cooled heat exchangers often require such large quantities of water that a plant, for instance a power station, has to be situated, often inconveniently, near a source of cooling water rather than near the source of its raw materials or its market.

The principal disadvantage of using air as a cooling medium arises from the very poor heat transfer coefficient between the air and the tube wall, which may be only 5 per cent of a water-film coefficient; this leads to large and expensive equipment. The low air-film coefficient can be improved by increasing the velocity of the air across the tubes, which also increases the mean temperature difference; but the advantages gained are offset by increased pumping charges. The rate of heat transfer may be raised, especially in dry countries, by injecting water into the incoming air stream; this reduces the air temperature and increases the mean temperature difference. Again, the surface area can be increased by using finned tubes, but this is expensive. None of these devices, however, gives more than a two- or three-fold increase in the heat-transfer rate and there is clearly a need for some method of raising the value of the air-film coefficient to at least that of a water-film coefficient. Such a device is described in this paper.

The Froth-contact Heat Exchanger

It has been found in this work and elsewhere[2] that if a froth is generated by coolant air around a tube bundle containing material to be cooled, the overall heat-transfer coefficient between the air and the liquid flowing through the tube is of the same order and sometimes better than that obtained in a liquid-liquid heat exchanger, where values between 150 and 300 Btu/ft² hr °F are usually encountered.[3] An explanation for this improvement is as follows:

It has been shown[4] that under suitable conditions the interfacial area of froth generated by sieve trays is 250 ft²/ft³. This contrasts with the low specific surface area of tubes; for instance, a bundle of 1-in. diameter tubes on a 1½-in. pitch has a surface area of 15 ft²/ft³. If the bundle of tubes is immersed in the froth, the transfer of heat from tubes to the air forming the froth can be regarded as taking place in two stages:

(1) The water surges around the tubes, which are wetted by a turbulent and frequently-renewed thin film. The heat-transfer coefficient to the film is high—apparently its value approaches that for submerged boiling—but the area of the film approximates to that of the tubes.

(2) The film on the tubes is replaced and carried away into the actively-moving froth. Here the heat-transfer coefficient is low, although not as low as a gas-film coefficient, owing to simultaneous mass transfer, but the area over which heat transfer is occurring is large.

Thus if U is heat-transfer coefficient, a is interfacial area per unit volume of the exchanger, t is temperature and subscripts T, F and A refer to tubes, froth and air respectively, in a steady state the rate of heat transfer is:

$$Q = U_T a_T (t_T - t_W) = U_A a_A (t_W - t_A)$$

Hence, the temperature of the water in the froth is

$$t_W = \frac{U_T a_T t_T + U_A a_A t_A}{U_T a_T + U_A a_A}$$

and

$$Q = \left(\frac{U_T U_A a_T a_A}{U_T a_T + U_A a_A} \right) (t_T - t_A)$$

Or, the overall coefficient, based on tube area, is:

$$U_a = \left(\frac{U_T U_A a_A}{U_T a_T + U_A a_A} \right)$$

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Indications from the experimental work are that the heat-transfer coefficient times the interfacial area in the two stages are not equal, and that t_W lies nearer to t_A than to t_T.

Some experiments by KASATKIN, POPOV and AKSEL'ROD,[2] who measured the rate of heat transfer from gas to water in spiral tubes during absorption on a bubble plate, show that the overall coefficient of heat transfer is about 150-200 Btu/ft² hr °F. These conditions for heat transfer are not ideal either in regard to the specific area of the froth or the arrangement of the tubes, and it was anticipated that even higher coefficients could be attained by using suitably-designed sieve trays and tube bundles. Accordingly, a small heat exchanger was built to investigate the properties of apparatus designed on this principle.

Experimental

The apparatus consisted of a sieve tray, approximately 1 ft², over which were placed two rows of copper tubes of ½-in. outside diameter. This is shown in Fig. 1, together with the weirs which control the froth height and permit the recirculation of the water over the tray. The tubes were placed on a square pitch of 1 in. The spacing of the tubes was made wider than usual, as the froth can attain its large interfacial area only if there is sufficient volume available for it to do so. The sieve plate was drilled with ⅛-in. holes on a 3-in. triangular pitch, this arrangement being known[4] to produce a turbulent froth rather than a stable foam over the plate at the air throughput to be used. Water was heated and passed through a tube in the bundle, the temperature of the inlet and outlet streams being measured by a thermocouple and a recording potentiometer. An air supply was connected below the plate, its temperature being measured by a thermocouple. A further thermocouple, placed well clear of the spray above the froth, was used to measure the temperature of the outgoing air.

The values measured from these experiments for the heat-transfer coefficient are given in Table I: it is seen that they are higher than would normally be found for a liquid-liquid heat exchanger.[3]

TABLE 1—Observed Heat-transfer Coefficients

	Air flow to sieve tray (cfm)	Heat transfer coefficients (Btu/hr °F ft²) of tube surface			
		Water in tube to air	Water in tube to outer tube surface	Tube surface to air	Tube to air with no froth
Single tube only in position	70	533	1890	744	2.5
	91	645	2160	919	
	121	635	2160	900	
	144	590	1910	854	
	168	527	1020	1090	4.3
Complete double bank of tubes in position:					
Centre tube top row	150	560	1400	933	
End tube bottom row	128	555	1400	920	
Fourth tube from end bottom row	150	570	1400	960	

This was unexpected, as it had been anticipated that the heat-transfer coefficient × the interfacial area in each stage would give the coefficient of a liquid to liquid heat exchanger, and hence an overall coefficient of about half this value. Evidently, the rate of heat transfer in each stage is high under frothing conditions.

Some experiments were carried out using only one tube and others with only a single tube carrying the heated water at several locations, in a bank of tubes. From the results it appears that the presence of other tubes, at least at the pitch used, has no significant effect on the value of the overall coefficient. The water-film coefficient for the inside of the tubes was calculated, and allowing for the resistance of the tube walls, the froth-side coefficient was determined from the experimental results. These values are given in Table I, where they are compared with calculated values of the heat-transfer coefficient which would be obtained were air flowing alone across the tubes.

The Design of Large-scale Units

The most important condition which must be fulfilled is the production of a mobile froth. A turbulent froth as opposed to a stable cellular foam is essential in view of the mechanism of the transfer of heat outlined above. The criteria to be satisfied in order to produce a fully turbulent froth are now well established and are as follows[4]:

(1) The Reynolds number of the gas flowing through the orifice ($Re_o = \frac{\rho u d_o}{\mu}$, where ρ and μ are the density and viscosity of air, and u is the velocity of air through the orifices of diameter d_o) must lie between 2000 and 5000.

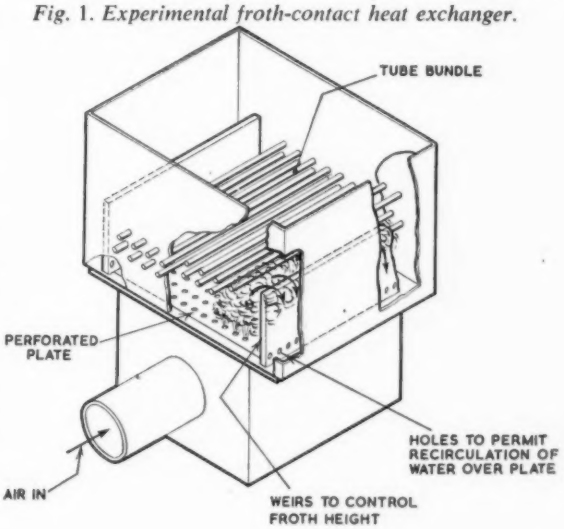
(2) The diameter of the orifices should lie between ⅛ in. and ½ in.

(3) There should be not more than 100 ⅛-in. holes or 50 ½-in. holes per square foot of plate. In practice, to keep the pressure drop down, as large an orifice as can be used with little dumping is desirable.

These criteria for good frothing limit the amount of air which can be put through a given area of sieve tray and to this extent limit the amount of heat which can be transferred in a given size of unit; there is no advantage in having a high heat-transfer coefficient and hence few tubes if these have to be placed over a large area of tray in a large piece of equipment. This is not an important limitation in practice, as will be shown: but, even so, those applications of the principle in which the amount of air used is kept to a minimum—that is, when it is permissible to allow the exit air to rise to a high temperature or in which some steam is generated—are likely to be the most worthwhile. A substantial fraction of the water is lost from the froth under these conditions, but this loss is a very small fraction of the water which would be required for ordinary water cooling.

The humidification of air is easy to carry out in the froth over a sieve tray and the air will nearly always leave the unit saturated. Some advantage is gained by this, especially in dry countries, because for a given heat load the temperature of the outgoing air is lower than it would be if the outgoing air were not saturated, and may even be lower than the temperature of the ingoing air. This increases the mean temperature difference and raises the rate of heat transfer; also the effective heat capacity of the

Fig. 1. Experimental froth-contact heat exchanger.



outgoing air is increased. This principle at present is sometimes applied in air-cooled heat exchangers by injecting a fine stream of water into the air stream or by allowing a trickle of water to flow down over the tube bundle.

Effect of Condition of the Air Streams

This is best shown by worked examples, which also illustrate the relatively small size of plant required for a given duty. We consider the design of an exchanger with a heat load of 10^7 Btu/hr: this exchanger would, for instance, cool 10,000 gal/hr water by 100°F, condense 50,000 lb/hr benzene or condense 10,000 lb/hr steam. In the calculations two factors are kept constant: the inlet air temperature at 60°F and the overall mean-temperature difference at 50°F.

Case I

Air enters dry and leaves at 100°F saturated with moisture.

Enthalpy of dry air at 60° = 14.413 Btu/lb

Enthalpy of saturated air at 100°F = 71.73 Btu/lb

If M is the mass flow rate of air:

$$M = \frac{10^7}{71.73 - 14.41}$$

$$= 1.74 \times 10^5 \text{ lb/hr dry air}$$

The volume of 1 lb dry air at 60°F is 13.096 ft.³ Thus, V, the volume of dry air required is

$$\frac{1.74 \times 10^5}{13.096} = 2.28 \times 10^6 \text{ ft}^3\text{/hr}.$$

The maximum value of Reynolds number (Re_o) of orifice on the sieve plate for a turbulent froth is 5000. The viscosity (μ) of dry air at 60°F is 12×10^{-6} lb/ft sec; its density (ρ) is 0.08 lb/ft³. Therefore, for ½-in.-diameter holes (d_o), the velocity of air through the holes is

$$u = Re_o \frac{\mu}{d\rho} = 5000 \frac{12 \times 10^{-6}}{1/24 \cdot 08} = 18.15 \text{ ft/sec}$$

If there are n holes on the plate we must have

$$\frac{2.28 \times 10^6/3600}{n\pi/4\ (1/24)^2} = 18.15$$

or $$n = 2.56 \times 10^4$$

At 50 ½-in-diameter holes per square foot of sieve plate, total area of plate (A) = 506 ft².

The overall heat-transfer coefficient measured experimentally is 500-600 Btu/hr ft² °F (i.e., per ft² of tube surface). Making an allowance for scaling of the tube surface and a reduction in the efficiency of contacting of the froth with the tube surface over a large area, we take the overall heat-transfer coefficient to be 200 Btu/hr ft² °F. Then the total surface area of tubes required at an overall mean-temperature difference of 50°F is:

$$10^7/50 \times 200 = 1000 \text{ ft}^2.$$

If the 506 ft² of sieve-plate area needed is arranged as a rectangle 25 ft by 20 ft, the 1000 ft² of transfer area can be obtained with 1-in.-diameter tubes, 25 ft long, of number

$$N = 1000/(25 \times \pi/12) = 153.$$

Saturated air at 100°F contains 0.0432 lb water per lb dry air. Thus, the water lost by evaporation is:

$$1.74 \times 10^5 \times 0.0432 = 750 \text{ gal/hr}.$$

The design of the exchanger therefore would be as follows: a sieve tray 25 ft by 20 ft is drilled with 50 ½-in. holes per square foot. About 4 in. above the tray 150 tubes, 8 per foot, are placed in a single line. Air is passed through the tray at about 2.3×10^6 ft³/hr, sufficient water being kept on the tray to form a froth to cover the tubes.

Case IIA

Air enters dry and leaves at 150°F saturated.

In this case less air is required.

$M = 3.83 \times 10^4$ lb/hr dry air;
$V = 5.02 \times 10^5$ ft³/hr dry air;
$n = 5.65 \times 10^3$ holes;
$A = 113$ ft² area of plate (say 16 ft × 7 ft).

The tube surface area is the same as before, that is, 1000 ft², requiring 238 1-in.-diameter tubes, each 16 ft long. Staggered tubes, 8 per foot, over an 8-ft width, need 4 rows of tubes one above the other. A froth height of about 1 ft, about the limit for a uniform turbulent froth, can easily submerge 4 rows and increases the water loss to 810 gal/hr.

Case IIB

As in case IIA, but the air entering is saturated.

$M = 4.02 \times 10^4$ lb/hr;
$V = 5.36 \times 10^5$ ft³/hr;
$n = 6.02 \times 10^3$ holes;
$A = 120$ ft² (say 15 ft × 8 ft).

255 1-in.-diameter tubes, each 15 ft long, arranged 8 per foot in 4 rows are required. The water loss is almost the same as in case IIA, and it will be noticed that the fact that the air enters saturated makes little difference to the exchanger size at the same mean-temperature difference.

Case III

Air enters dry and leaves at 200°F saturated with moisture.

$M = 3.75 \times 10^3$ lb/hr;
$V = 4.91 \times 10^4$ ft³/hr;
$n = 552$ holes;
$A = 11$ ft² (say 6 ft × 2 ft).

636 1-in.-diameter tubes, each 6 ft long are required. With a width of 2 ft at 8 tubes per foot, 40 rows would be needed. Restricting the number of rows one above the other to 8, 5 sets of sieve plates, each with 8 rows of tubes, the sets placed conveniently one above the other, would be a possible design. The water loss is 883 gal/hr.

For this case it may be more convenient to use a lower orifice Reynolds number, say 2000. Then the area of sieve tray required is 28 ft² (7 ft × 4 ft), needing 550 1-in.-diameter tubes, each 7 ft long, which at 8 per foot requires 17 rows, that is, 2 sets of 8.

Thus the exchanger size depends critically upon the exit air condition. Air saturated at 200°F has a very much greater enthalpy than air at 100°F and this reduces the amount of air needed by a factor of 50. The area of sieve plate required and the physical size of the exchanger are reduced by the same factor, so that with air leaving at 200°F the unit is no bigger than the equivalent water-cooled exchanger. The calculated loss of water stays about the same in all cases, for the water content of the air rises in proportion to the fall in the amount of air needed. In practice it is likely that some water would be entrained and some steam carried off, that is, the air would be supersaturated. Even so, the total loss of water is a small fraction of that which would be required to effect water cooling and, excepting extreme conditions, is not an important consideration.

The authors believe that the froth-contact air-cooled exchanger has economic advantages over the water-cooled exchanger, even where water is plentiful, and that it is certainly superior to both air- and water-cooled exchangers where water is in short supply. Further work on pilot-scale exchangers of this type is contemplated.

ACKNOWLEDGMENTS

The work described in this paper forms part of the research programme of Warren Spring Laboratory and is published by permission of the Director.

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RECENT DEVELOPMENTS IN MATERIALS OF CONSTRUCTION

Topics discussed in this report include the corrosion resistance and use in chemical plant of recently developed wrought nickel alloys and the "newer" metals such as titanium and tantalum. The development of plastics as materials of construction is outlined, and in some instances costs are compared with traditional materials. The glass fibre wound laminating technique for vessel and tank manufacture, with its advantages, are described. Developments in modern ceramic technology are briefly outlined.

by T. R. BOTT

THE Midlands Branch of the Institution of Chemical Engineers recently held a one-day meeting on "Materials of Construction" in the Chemical Engineering Department of the University, Birmingham. Five papers were presented, the first four being discussed at the meeting. The morning session was devoted to new metals and alloys, the chair being taken by PROFESSOR F. H. GARNER, O.B.E. During the afternoon session papers were presented on plastics and ceramics under the chairmanship of MR. K. M. CURWEN, Chairman of the Midlands Branch. Some 135 delegates from all parts of the British Isles registered for the meeting.

An exhibition illustrating four of the papers proved an attraction. Examples of the use of new metals and alloys with reference to the chemical industry were displayed. A tank manufactured by the glass-fibre wound laminating technique was shown together with various items of interest fabricated from plastic materials.

Fabrication and Properties of Some of the Newer Constructional Metals

by N. P. INGLIS
(I.C.I. Metals Division)

IN recent years engineers and scientists have demanded development of metallic materials for very specialized purposes. Many of the requirements have been met by the so-called "new" metals, such as titanium, zirconium, beryllium, niobium and hafnium.

The general method of manufacture was outlined for each metal, indicating the high degree of technical skill required to achieve the desired products. The main emphasis of the paper was on the fabrication and properties of each of the metals.

Zirconium and hafnium are found in association so that the economics of production are closely linked. The outlet for beryllium and niobium, at the present time, is the specialized field of nuclear engineering. Titanium and tantalum are of more immediate interest to the practising chemical engineer, with niobium likely to be of interest in the near future.

Commercially pure titanium is produced in several grades of differing hardness, tensile strength and ductility. The softest grade has a tensile strength of 26 tons per sq. in., whereas the hardest grade exhibits a tensile strength of 40 tons per sq in., but is still ductile enough for pressing, drawing, spinning, etc.

The strength of commercially pure titanium falls fairly rapidly with temperature, but this feature can be substantially improved by alloying. Some alloys show good load carrying properties at a temperature as high as 500°C. Extensive research is being conducted with a view to improving this aspect of titanium technology.

Titanium is resistant to a wider range of corroding agents than chromium-nickel austenitic steels. The corrosion resistance is attributed to a thin surface oxide film which is difficult to remove. Titanium is therefore particularly resistant to oxidizing liquors, e.g., all strengths of aqueous nitric acid up to boiling point. The metal is resistant to alkali solution of low or medium strength and shows considerable resistance to attack by sea water. Anodic passivation of the metal is also possible.

The use of titanium as a material of chemical plant construction is increasing. A selection of items manufactured from titanium were listed in the paper, amongst which was a heat exchanger handling wet chlorine.

Fusion resistance, flash-butt and pressure welding techniques can all be applied to titanium, provided the right safeguards are employed.

The main use for niobium in chemical plant construction is its basis in a temperature-resistant alloy for high-temperature reactions. The metal has a high melting point (2470°C) and good strength at elevated temperatures, these properties being somewhat offset by extremely poor resistance to oxidation at such temperatures. Work is being carried out in the U.K. and U.S.A. to devise an alloy, possibly in conjunction with an oxidation-resistant coating which will overcome these disadvantages.

A limited amount of tantalum metal has been used for

T. R. BOTT is a lecturer in Chemical Engineering at Birmingham University. He is Hon. Secretary of the Midlands Branch of the Institution of Chemical Engineers.

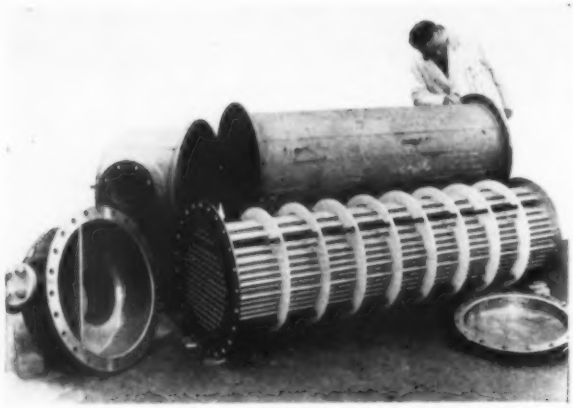

Fig. 1. Titanium heat exchanger made by Marston Excelsior Ltd., and required for wet chlorine service.

a number of years in chemical plant on account of its very good corrosion resistance. Tantalum heads the list of corrosion-resistant metals mentioned by DR. INGLIS, and is exceptional, since it is resistant to hydrochloric acid, even concentrated acid at high temperature. It is totally inert to the lower halogens, wet or dry, up to a temperature of 150°C and at higher temperatures if the halogen is dry, but it is attacked by fluorine.

The very high reactivity of tantalum at high and molten metal temperatures prevents the use of many of the standard methods of welding the metal. Resistance and fusion tungsten argon arc welding can be applied to tantalum, provided adequate precautions are taken.

The costs of these "new" metals is high, but will reduce as production methods improve and output is increased, although, by the very nature of the problems of production, the cost is likely to remain above those for the more common metals.

DR. INGLIS concluded his paper with a plea that engineers must design for these metals rather than merely substituting new metals for old.

Recent Developments in Wrought Corrosion-resistant Nickel Base Alloys

by ERIC WARDE
(Henry Wiggin & Co. Ltd.)

THE development of the chemical and petroleum industries in recent years has led to the use of more drastic operating conditions, resulting in a need for better corrosion-resistant metals. Nickel alloys, with a high degree of corrosion resistance, have been developed and are being developed to meet this challenge. MR. WARDE restricted his remarks to four alloys and for clarity these were referred to by their appropriate trade names.

"Incoloy" is a nickel-chromium alloy developed for plant carrying out pyrolysis and reforming operations. In the production of ethylene by pyrolysis of liquid fuel stocks "Incoloy" has been shown to be an effective material of construction. Providing oxidizing conditions are maintained within the reaction tubes, sulphur contents of up to 1 mole per cent can be tolerated in naphtha and gas oil feed stocks. Failure of the tubes by carburization can be avoided by good temperature distribution, and by attention to design and constructional details such as the restricted use of tight radius return bends or excessive penetration of welds. During decoking operations high temperatures and oxidizing conditions can be produced, and the tubes could fail due to conversion of chromium carbide to oxide. "Incoloy" tubes can have a life expectancy of 5-6 years provided careful temperature control is employed and the mean skin temperature does not exceed 760°C during decoking operations.

Where control can be exercised on the furnace side atmosphere, oxidation is not a problem with "Incoloy" tubes; sulphur can be tolerated up to 0.5 mole per cent sulphur with 20 per cent excess air. "Incoloy" is not susceptible to tubercular growths which have been encountered with other alloys.

A nickel-molybdenum-iron-vanadium alloy known as "Corronel 220" has been developed for resisting the attack of non-oxidizing mineral acid and is free from weld decay. The major industrial outlet for this type of alloy is in contact with acid chlorides. The alloy shows considerable promise as a material of construction in plant producing chlorinated hydrocarbons, with hydrogen chloride as a by-product, where small quantities of moisture are present, or in the Friedel Craft alkylation processes. MR. WARDE suggested that alloys of the "Corronel 220" type could also be used in plant handling phosphoric and sulphuric acids.

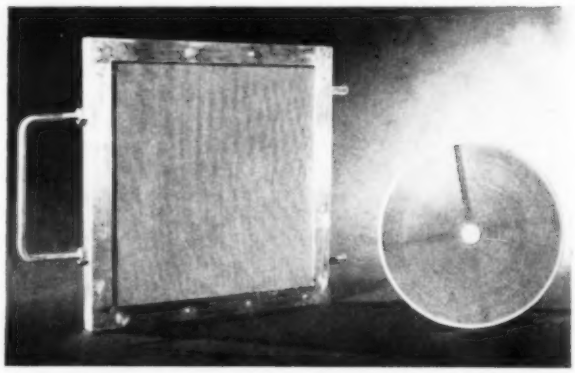

Fig. 2. Flame traps in "Ni-O-Nel" (left-hand side: Ferguson & Timpson Ltd.; right-hand side: Amal Ltd., Witton).

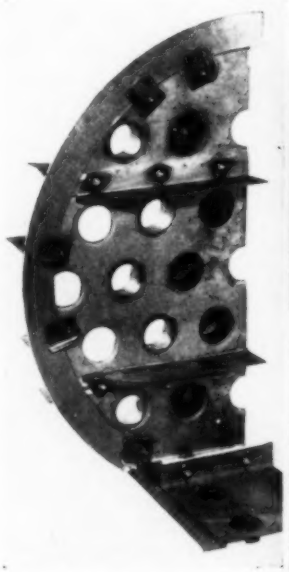

Fig. 3. Glitsch tray in "Corronel 220". (Metal Propellers Ltd., Croydon.)

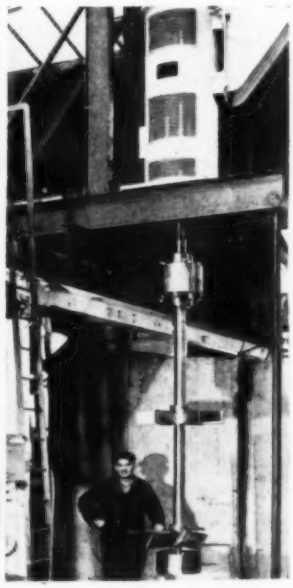

Fig. 4. Agitator in "Ni-O-Nel" for sulphuric acid washing of benzene. (L. A. Mitchell, Manchester.)

Alloys of nickel and molybdenum are adversely affected by oxidizing agents containing the nitrate, chromate, ferric or cupric ions, so that these conditions must be avoided with "Corronel 220".

"Corronel 230" is a nickel-chromium alloy offering resistance to nitric acid. It displays excellent resistance to attack by nitric acid-hydrofluoric acid mixtures. Uses envisaged for this material are valves, pumps and other mechanical items of chemical plant.

"Ni-O-Nel" is an austenitic nickel-chromium molybdenum-iron alloy developed to resist pitting and stress-corrosion cracking. The alloy exhibits a high order of resistance to attack under oxidizing acid conditions.

This alloy has found use in coolers employing sea or poor quality water to cool nitric acid, sulphuric acid containing oxidizing agents or phosphoric acid liquors containing fluoride ions. Attention was drawn to the potential use of "Ni-O-Nel" in esterification equipment. The usefulness of the material in process plant associated with sulphonation of aromatic compounds and in general handling of acid/hydrocarbon mixtures has been demonstrated. Resistance to organic acids is also offered by "Ni-O-Nel".

The fabrication and construction of plant and equipment with these four alloys presents no difficulty provided that precautions are taken in certain situations.

MR. WARDE forecast that within the next decade further developments in nickel alloys would be made, but these advances would depend upon the operating conditions being sufficiently detailed for the problems to be clearly defined.

Thermoplastics in Chemical Engineering and Building

by S. SLANEY
(Shell Chemical Co. Ltd.)

MR. SLANEY dealt with several thermoplastics in turn. Polyvinyl chloride (P.V.C.) is a well-known thermoplastic, the total output of which is larger than any other similar material. Compounding with various fillers and plasticizers results in a material which is extremely versatile, and can be readily converted to sheet form or processed into pipes, joints, etc.

P.V.C. pipes and tubes are suitable for handling concentrated acids and alkalis, alcohols, detergents and sewerage. The tubes are hydrodynamically smooth, thereby reducing operating costs. Maintenance costs are low due to good weathering characteristics and no painting is required. The maximum permissible working temperature is, however, limited to 40°C. MR. SLANEY made a comparison of the installed cost of a 380 ft run of 12 in. diameter pipe in P.V.C. of £1880, with an estimated cost of £1931 for a similar installation in mild steel. This demonstrates the competitive price of P.V.C. pipes.

P.V.C. has also found extensive use as a lining material for vessels and as a coating material for pump and valve parts.

Hot air and solvent welding can be employed in the fabrication of articles from P.V.C.

Polyolefins have also been developed for chemical plant construction. High and low density polyethylenes are well known; a more recent product is polypropylene. The major advantage of the latter is its higher maximum working temperature (its yield stress at 100°C is 30-40 per cent that at room temperature).

Polyethylenes display excellent resistance to non-oxidizing acids and alkalis at normal temperatures. Below 60°C polyethylenes are not generally affected by organic solvents, but at higher temperatures the material is attacked by hydrocarbons and halogenated compounds. The chemical resistance of high-density polyethylene is greater than the low-density variety, and maintains its physical properties down to temperatures of −70°C.

Fig. 5. A 13,500-litre glass-fibre reinforced-plastic transport container mounted on its lorry.

Cost figures presented in the paper show that prices for low-pressure pipe of 1 in. and 1.5 in. bore fabricated from high- and low-density polyethylene (and incidentally P.V.C.) are competitive with low-pressure mild steel pipes.

Polyolefin sheet has been used for some time for the fabrication of vats, tanks and ducts using hot air welding techniques for construction. Cladding of steel with these materials has also been developed utilizing a rubber interlayer to take up differential expansion.

Moulded joints, valve parts, pipe fittings, etc., have been made from polyolefins. The replacement of cooling tower grid packings by grids of high-density material has resulted in an overall increase in efficiency.

Spheres blown from high-density polyethylene have been successfully employed on the surface of corrosive liquids to prevent splashing and heat loss. Evaporation from the surface of stored liquids has been restricted by this method.

Other plastics mentioned by MR. SLANEY included nylon,

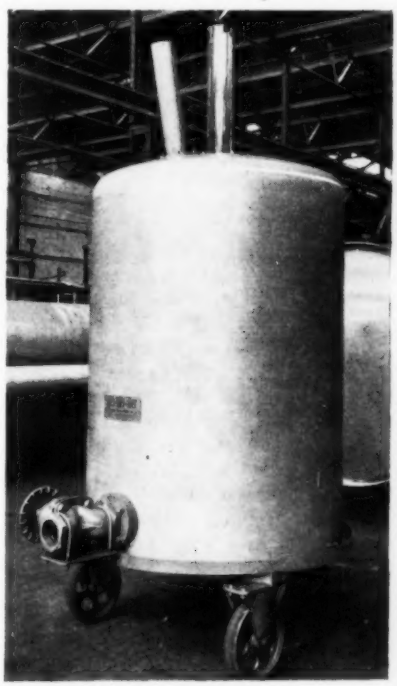

Fig. 6. 1000-litre measuring vessel for jet fuel from glass fibre reinforced plastics.

which is usually restricted to special applications on account of cost, and polymethylmethacrylate which is used for optical applications, e.g., inspection covers, etc.

Recent developments with the copolymerization of styrene with acrylonitrile and butadiene have produced materials with outstanding chemical resistance. These are widely used in the U.S.A. for piping applications. Brief mention was made of expanded polystyrene as an insulating material.

New plastics mentioned were polycarbonates and polyformaldehyde. The former has high impact strength and high softening point, but is attacked by alkalis; the latter is a tough rigid plastic with good impact and tensile strength with excellent chemical and solvent resistance and is suitable for accurate moulding. At present these two materials are not manufactured in the U.K.

Glass-fibre Wound Laminates

by F. F. JARAY
(Consultant)

THE speaker stressed the advantages of producing laminates by some form of winding technique. The raw material is cheap and can be applied in the direction of stress, and the process can be carried out mechanically, thereby reducing the "human element". Most tanks and vessels in the chemical industry are cylindrical or prismatic in shape, thereby lending themselves to the winding process.

A winding machine, which is basically a type of lathe, is used to produce the articles. A mandrel which corresponds with the inside of the vessel is revolved at a suitable speed, whilst the "tool-holder" carries and feeds the bundle of glass fibres on to the work. The fibres can either be treated with resin at the "tool-holder" or in a stationary tank or the fibres could be pre-impregnated.

Most stresses in a cylindrical object can be analysed as hoop stresses or axial stresses, and accordingly the reinforcement can be applied around the circumference or axially. Alternatively, the components of stress can be combined into a resultant at a certain angle to the axis and the reinforcement applied in the direction of the resultant. This is known as helical winding. A reasonable figure for resin content is 30 per cent, which can be maintained within fairly close limits with careful control. Tank ends need special attention if the working pressure of the tank is to be above 30-50 psi.

The fibre winding technique for manufacturing vessels enables the shell to be treated mathematically. It can be shown that for vessels where internal pressures are high and diameters are small a solid construction of wound glass fibre laminate will be technically and economically the most advantageous. Where the internal pressure is low and the vessel diameter large, it is more economical to use a sandwich construction when it is possible to utilize cheap natural fibres or honeycomb or foamed material for the inner layers.

DR. JARAY mentioned two methods of improving the glass-fibre laminates. The first is to pre-stress the fibres, preferably by the use of an expanding mandrel, so that as the resin shrinks on curing the fibre remains in the stretched condition. The second is to line the tank with an impervious layer of a different resin, thus preventing the fibres from becoming wet during subsequent use.

Vessels made by this method cannot be used at temperatures more than slightly above ambient temperature, for at temperatures in the region of 80-100°C the behaviour of all laminates changes fundamentally—at these temperatures the strength of glass fibre laminates falls quickly to and below that of the unbound fibre bundles.

Glass-fibre wound laminated vessels have been successfully used for the storage of such chemicals as phthalate and the transportation of wine.

DR. JARAY ended his paper by saying that glass-fibre wound structures will find use wherever overall corrosion resistance and light weight are desired, the cost being not much more than twice the price of ordinary mild steel.

High-temperature Ceramics

by A. T. GREEN
(Consultant)

DR. GREEN stated that it was becoming increasingly difficult to define the limits of the ceramic industries. The field of ceramic technology has extended beyond the basis of clay and now includes the development of certain oxides, carbides and nitrides.

The basic refractory for the steel industry has been considerably developed over the past quarter century. Recent research with the chrome-mangesite brick for the steel furnace roof has permitted the use of higher temperatures in the basic open-hearth steel making process with attendant increased output.

At the present time the ceramic industry is developing the use of high purity oxides, carbides and nitrides and related compounds. Fabrication of an article in these materials can be achieved by pressure forming, slip casting, extrusion, spraying or hot pressing. The technology of these processes applied to the newer materials requires considerable development.

In pressure forming, variations in density cause trouble in the use of the product—the contributing factors to density variation need careful study. There is a growing future for hydrostatic or isostatic moulding where the pressure is applied evenly all around the mould.

The technology of slip casting, used on clay materials for two centuries, is being developed for the non-clay materials, although there are difficulties to be overcome. Slip casting of these oxides will eventually reduce high production costs, particularly the need for costly dies. Slip casting techniques have been applied to alumina and magnesia and some other oxides calcined at high temperatures.

The study of hot processing, besides producing certain articles of low porosity, and therefore high density, has been helpful in the study of sintering.

DR. GREEN concluded his talk with a brief review of the properties and use of products made from alumina, beryllia, magnesia, silicon nitride and dense silicon carbide.

IN OUR NEXT ISSUE

The Economic Analysis of Liquid-Liquid Extraction Processes
by V. G. JENSON and G. V. JEFFREYS

A Hydraulic Analogue for Transient Heat Transfer Problems
by ING. CARLOS DUHNE

Bulk Handling of Powders in the Chemical Industry
by F. E. D'ARCY-SMITH

Difficulties of Organic Acids in Ethanol-Water Mixtures
by G. N. BHAT

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PART II

SURVEY OF DIGITAL COMPUTER APPLICATIONS IN THE UNITED STATES

by J. J. TABOREK

Through a number of economic factors, the United States at present leads in the industrial use of digital computers with respect to number of units in operation, their size and programme development. Some examples of the types of problem solved are given and the effects of these solutions upon the process industry are discussed

THE application of digital computers has become so extensive in the last few years that an attempt can be made here to outline only the most important problem types, with emphasis to applications in the process and petroleum industry. Basically, the computer problems will fall into one of the following categories with respect to the economy of computer use:

(1) Problems involving simple but frequently repeated calculations and handling large quantities of data material. These are typical business problems and the use of computers is expected to reduce human errors, decrease the time of processing and access to stored information and, last but not least, to reduce the number of employees required for the job.

(2) Problems requiring lengthy and tedious calculations but of such a type, that they are being (or could be) presently done by hand or desk calculators. Most engineering problems fall into this category. The speedup of calculations and eventual saving in manpower, however welcome, is considered only incidental. The main advantage of computer use seems to lay in the fact that having the computer available, the engineer will be able to study his case much more thoroughly than he would have otherwise, arriving at designs with economic optimum.

(3) The third class are problems which, on account of their size, are solvable only with computers. We find here problems with partial differential equations, data correlations and economic optimizations frequently involving systems with thousands of simultaneous equations. The economic advantages of computers in such cases are, naturally, individual.

Within the physical limits of the available computer machinery, the capabilities of computers are largely dependent on the imagination of the analytical and programming staff.

It is rather difficult to generalize on the differences in the philosophy of problem solutions by computers versus manual methods but several points should be mentioned as typical.

(1) The ingenuity and individual approach by the manual solution method is replaced by computer speed and rigid logic system. The programme must account fully for all situations which may develop, e.g., combinations of subresults which are improbable and would be easily taken care of by human reasoning.

(2) Tabulated information, graphical charts, etc., must be, in most cases, converted into equations no matter how complicated. Even more difficult are decisions based on engineering experience and standard practices which also must be converted into equations or mathematically expressed criteria.

(3) Problems which are likely to be encountered frequently in the same or similar form are often developed into general type programmes. This is particularly true about the Data Correlation and Engineering Type Problems. In such cases the programme provides for any possible variation of the parameters, solution type, subresult treatment, etc., which may be useful to a complete investigation of the case.

In the following chapters, ordered into groups of technical similarity, the use of computers to the most important problems in the process industry will be briefly surveyed.[8, 9]

Problems in Applied Science

A number of scientific and engineering problems are based on the Navier-Stokes partial differential equation of the form:

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial y^2} = a\,(x,y)$$

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Problems of heat conduction, pressure field distribution, stress analysis and electrostatic and electromagnetic field potentials are typical examples.[1] If the boundary has a complicated shape the only practical solution is by numerical integration using the so-called Relaxation Method. The derivatives are replaced by finite differences in a grid network where the boundary shape and conditions at the grid points can be described. The size of the grid field and the increments of the often encountered time parameter must be chosen quite small if a good accuracy is to be reached. Under such conditions it is obvious that the computer is a necessary requisite and machines with large storage are often required.

Applications of this method to heat conduction problems are reported.[2] Predictions of petroleum reservoir performance are based on a similar approach.[3] From the corresponding elliptical differential equations the field potential can be calculated as a function of the permeability of the production formation layers. As a result, the field production recovery by water flooding and the optimum locations of the injection points can be predicted from the calculated floodout pattern of the field.

Process Control

The first applications of digital computers to process control were interpretations of instrument readings, e.g., of an absorption spectrometer. The computer, with its speed, could supply the results so fast that an effective control of the process became more practical. The next logical step was to tie the instrument observations to the intermediate variable controls (temperature, pressure, flow, etc.). The computer becomes, in this case, an integral part of the process system. The data of the measuring instruments are fed to the computer, and evaluated by the programme on the basis of optimum process operation. The computer output is in the form of commands to the automatic controls (Fig. 1). Digital computers used in such a set-up are said to operate in "real time". This designation is derived from the fact that their performance is tied, with respect to time, as a part of the actual process.[4, 17]

There is a controversy between the adherents of analogue versus digital computers for the process control functions. While there will be advantages of the analogue computer for single control operations, the digital machines seem to be the logical choice for a larger scale control system, where the flexibility of the latter will be superior to the analogue machines. The digital computer programme will incorporate provisions for a variety of possible conditions, including changes in feed stock, variations of product quality, emergency situations, etc.

Several refineries and chemical plants in the United States are reported to be under partial computer control and rapid progress in this field in the next few years is definitely to be expected. When successful, such large scale process control will substantially increase the efficiency of the plants and, eventually, commercial utilization of such processes will be realized, which for the inadequacy of the human operator were up to now impossible.

Process Simulation

The first digital computer applications to process simulation were "case studies" often referred to as "Plant Heat and Material Balances". Figure 4 shows a schematic flow diagram of a process. For each of the process units a mathematical model of its operation must be known as well as the composition and properties of the input material. From these data the computer programme simulates the processing, reiterates within the flowloops until a steady state of operation within a certain percentage of convergence has been reached. By varying the feed material and eventually the location and operational characteristics of the single units, the engineer can obtain a wealth of information before certain changes or new designs are actually put into operation.

Having mastered, at least in theory, the problems of single process simulation and control, the computer analysts are suggesting the next bold possibility: using the computer to simulate parts or complete chemical processes including their control on any desired scale entirely by computers. Problems of such magnitude require a substantial computer memory storage but the present large machines and the new computers under development are entirely capable of handling these requirements. The advantages of such process simulation are obvious: the pilot plant operations could be substantially simplified and the time between the conception of a process and its commercial utilization would be drastically shortened.

Before such schemes become practical, the plant simulation programmes are being extended to include economic study of the value of products and by-products. This has been brought to practical perfection in the oil industry in the simulation of complete refinery operations. The engineer can study the effect of varying feed composition and adjust the output of various type products to overall economic optimum.

Application of Statistical Methods

The advent of the computer into United States industrial organizations has resulted in an unprecedented expansion of statistical activity. All phases of the statistical science of collecting, analyzing, and interpreting empirical data are stimulated by the rapidity with which once seemingly impossible magnitudes of tedious operations can now be economically processed.

The computer data processing system has streamlined the maintenance of statistical records. Large masses of data can now be filed in a convenient form to permit a rapid performance of additional processing functions such as: file updating, sampling of records, integration with other data sources, etc. The high accessibility of stored data makes the analysis of a company's operational problems more precise and more practical than was possible a few years ago. The computer-oriented system for processing historical and statistical data has thus advanced beyond mere record keeping into the area of recording data for maximization of its future utility.

The digital computer's ability to perform high-speed calculations coupled with its ability to make built-in logical decisions is being used extensively in various types of statistical analyses. Time series are being rapidly calculated from source data. Means, standard deviations, and other descriptive statistics of an unknown distribution are being rapidly produced for many variables. Data resulting from all types of controlled experimentation are being collected and analysed in correspondence with "experimental designs" based on statistical methods for their maximum utilization. Accumulated data are subjected to regression, auto-regression, correlation, and auto-correlation analyses. The complex problems of computing statistical estimates and their confidence limits for multi-parameter systems are now being successfully attacked. Multi-variate analyses such as discriminant function analysis, factor analysis, and canonical analysis are now feasible models from the computation standpoint. In addition to applied statistical problems, the computer is being used to calculate tables for various theoretical distribution functions, e.g., the non-central t-distribution.

The computer's ability to calculate rapidly values from various theoretical distribution functions is being utilized in conjunction with operation research type problems. This ability makes the study of models involving chance processes feasible. Complicated economic models of inventory and

production scheduling are being simulated on the computer with the inclusion of chance phenomena.

Industrial Applications of Operations Research

Operations Research is a term applied to an area of scientific effort which draws upon all disciplines for its methods and techniques, and whose primary objective is the optimization of an existing or projected activity. The methods of Operations Research involve constructing a model of the activity to be studied, where the essential conditions, restrictions and relationships among all elements of the activity are defined as precisely as possible. An optimal pattern for operating the activity is then sought by manipulation of the model. It may be impossible to obtain an optimum solution, particularly if some essential phase of the activity cannot be treated within the restrictions imposed upon the problem, but the consistent aim of Operations Research is to reach an optimum, or get as close to it as possible.[13, 14]

The use of Operations Research methods by private industry has spread rapidly since 1951. The primary reason behind this trend toward scientific methods was, undoubtedly, the increased availability of high speed computers. Industrial applications of Operations Research can seldom be handled efficiently by pencil and paper methods of calculation. For this reason, Operations Research first took hold among the larger corporations where computers were available. Today, even the small manufacturer, who cannot justify a permanent Operations Research staff within his organization, may profitably introduce Operations Research methods by retaining a computer service agency to develop and run his programmes.

For the purpose of our present discussion it is convenient to group the applications themselves into seven more or less discrete categories:

Transportation Problems—Distribution of product from n sources to $n + k$ destinations in such fashion that transportation costs are a minimum. Typical algorithms accommodate special objectives such as optional selection of plant or warehouse locations and capacities; determining the "best" allocation of product when demand exceeds supply, etc. Small matrices are readily resolved by hand, but industrial problems often generate matrices 30×100, and even 100×800 is not uncommon.

Maintenance and Replacement Problems—Such problems can be grouped according to the pattern of efficiency loss associated with the equipment to be maintained. In other words, does the equipment fail (light bulbs) or does it simply lose efficiency by reason of long usage or new technical developments? For equipment that fails, the problem is to determine which units to replace, and the frequency of replacement, in a way that minimizes the combined costs of equipment, failure and replacement. For deteriorating items, the task is to time replacement so that the costs of equipment, replacement and loss of efficiency are a minimum. In general, maintenance work involves the replacement of parts or components rather than replacement of an entire piece of equipment. The issues are essentially alike, and the same approach is used on both replacement and maintenance problems.

Inventory Problems—Decisions as to (1) what volume to purchase or produce; (2) when to initiate a purchase or production order. Account is taken of the balance point between the cost of carrying inventory and the cost of production change-over set up, inventory shortage, and delays.

Allocation Problems—When there are alternative ways of performing each of several activities, and when resources or service facilities are not available for handling each activity in the best way, the problem becomes one of balancing activities against resources in a way which maximizes overall effectiveness.

Service-Delay Problems—These problems involve balancing service facilities against the demand upon such facilities. Generally, waiting time is involved affecting either the units arriving at the service facility, or the facility itself. Either type of delay incurs a cost. The problem is one of controlling the arrival of units requiring service, or in determining the size of service facilities which minimizes both kinds of costs.

Strategies—When the potential value of a management decision can be increased or decreased as the result of the actions or decisions of competitors, the problem is one of optimizing strategy. The Operations Research approach to such problems involves game theory. Current applications mentioned in the literature deal with the strategies of competitive bidding.

Simulation of Large Activity—If a plant is capable of producing a variety of products subject to variable demand schedules, management's problem is to maintain an optimum economic balance among all activities in which the plant may engage. The problem is to discover the combination of operating levels among all phases of the process which will produce an overall optimum; this usually proves to be something other than the sum of the individual process unit optimums.

A model capable of simulating a complex industrial plant will generally include sub-models of activities such as those described in preceding paragraphs or it will make use of engineering simulations of the processes involved, such as the heat and material balances; the result of these components as interpreted by the operation analysis will eventually become a highly sophisticated model involving optimization under 200 or more restraint equations.[13]

Engineering Problems and Equipment Design

Any engineering problem is suitable for evaluation by computers as long as it can be formulated by equations and other mathematically precise decision criteria. Not all such problems, however, will represent an economically sound proposition for computer use. The time involved in programming, coding, and checking out can be impractical for problems which are required for singular use. Automatic programming systems and small desk type computers with simple coding language are of considerable help for such cases.

Of greater importance are problems which are required for repetitive use and where elaborate and general type programmes are justifiable. Problems for design of engineering equipment which is repeatedly used in a company belong in this category. A computer programme, however, should not only duplicate the respective hand calculation method but should include provisions for solving a broad spectrum of design possibilities, indicating to the engineer a direct or indirect way to economic optimum design. The following examples are selected as typical of computer utilization in this field.

Reactor design—The first step in a fundamental approach to chemical reactor design or simulation is the determination of a kinetic equation for each reaction which proceeds to a significant extent. These rate equations provide quantitative information on how fast each reaction occurs. For the simultaneous reactions:

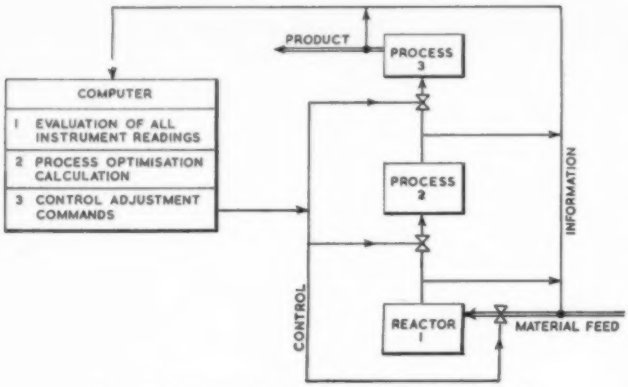
$$A \xrightarrow{k_1} P + Q$$

$$A + B \xrightarrow{k_2} R$$

The corresponding equations are as follows:

$$-\frac{d C_A}{dt} = k_1 C_A + k_2 C_A C_B$$

$$-\frac{d C_B}{dt} = k_2 C_A C_B$$



▲ 3 *Schematic diagram of process control by digital computer.*

$$\frac{d C_P}{dt} = k_1 C_A$$

$$\frac{d C_Q}{dt} = k_1 C_A$$

$$\frac{d C_R}{dt} = k_2 C_A C_B$$

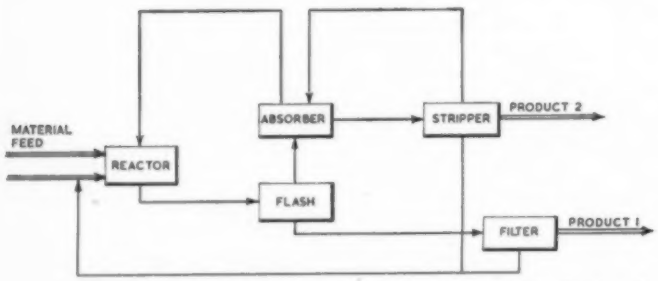
With this data we can compute the relationship between conversion in each reaction and the length of time the reactions have been taking place, that is, the contact time or residence time in the reactor vessel. Moreover, if the effects of controllable process variables (such as temperature and pressure) upon the rate equations are known, then it is possible to vary reactor conditions to search for an economic optimum.

In cases of simultaneous and/or consecutive reactions it is not always correct to simplify the picture by considering only the gross effects of reactants converted to products. Each reaction must be treated individually.[5] Obviously, an extensive calculation problem results especially if the number of reactions and the number of components are large. The computer is an almost indispensable tool for evaluating such complex cases.

Once the kinetic data have been obtained the process can be simulated by the computer and, eventually, translated into actual design and operational criteria. In fact two recent articles[6, 7] have shown how a large computer can actually replace a pilot plant if the kinetic data are sufficiently accurate.

Fractionator Tower Design

The most common symbol of the oil industry is a derrick but an equally good symbol would be a fractionating tower. Thirty years ago, fractionation was virtually the only operation carried on in refineries, and if today a wide variety of reactors, mixers, dryers, and other operations have invaded refineries, the role of fractionation has become even more important.



▲ 4 *Flow chart for process simulation of the heat and material balance.*

For this reason the first major engineering operation to be calculated by a digital computer at Phillips Petroleum Company was fractionating towers. The need for high speed calculations of fractionators came out of the need for gasoline of closer specifications and a new market for hydrocarbons such as butadiene, ethylene, cyclohexane, benzene, toluene and others. Up until recently, many refining columns were designed by arbitrarily putting in a certain number of trays and setting the reflux to feed ratio at a value that appeared reasonable. Even now, this is sometimes adequate. For fractionators where the separation was more important, simple equations which treated multi-component mixtures as approximations to a binary feed were used to calculate the reflux rate and number of trays required. As the need for better designs increased, some calculations were made by hand using the tray-by-tray concept. However, the time used in these calculations was excessive. The concept of absorbing and stripping factors was developed. These methods of calculating fractionators were much faster than tray-by-tray calculations, and almost as accurate. However, considerable skill and practice were necessary and even with this method the time required to calculate one case might run as long as a week. This combination of time and skill requirements limited their usefulness.

Thus, there was an increasing need for high speed fractionator calculations, particularly for such processes where the effects of intercoolers, side draws, and multiple feeds were to be incorporated.

The basic concepts in tray-by-tray fractionator calculations are well known, and there is no particular problem in programming them on an adequate computer. Starting at the kettle product and the overhead product, a tray-by-tray calculation can be made to mesh at the feed tray. For example, starting with an assumed kettle product, the steps shown in Fig. 5 can be used to calculate the composition of each successive tray in the stripping section up to the feed tray. If check in step 9 is satisfied, the programme advances to the next tray, if not satisfied, it regresses V_0, and repeats 4 through 9. The subscripts 0 and 1 refer to the tray being calculated. For a computer of adequate storage (approximately 3000 programme statements and data numbers is the minimum for basic fractionator calculation) coding of a tray-by-tray fractionator calculation is not difficult. However, three questions do come up during the programming.[16]

(1) In what form should the heat and equilibria data (step 1) be entered? Each company has somewhat different problems that affect their choice. Our choice was a polynomial in temperature for both enthalpy and equilibrium data. Most of the hydrocarbon mixtures processed by Phillips do not deviate appreciably from an ideal mixture. Also the data available is usually pure component data and elaborate methods of curve fitting the data did not seem justified. Our programme does provide a method for easily adding special programmes to calculate correction factors based on composition. We have encountered so many different ways of correlating equilibrium data with composition that it seems easier to treat each as a special case rather than to try to make a general programme that could handle all cases. The programme used a simple method for correcting pressure changes when this was required. The equilibrium data was curve fitted at the bottom pressure and a correction factor was found which would convert the equilibrium "K" values of this pressure to the pres-

sure in the top of the column. The equilibrium "K" value for any tray can then be determined by linear interpolation of this correction factor.

(2) The second question which the analyst will face is how to converge on the vapour leaving each tray (step 4). The Phillips programme uses the Newton method: solves a simultaneous equation involving the partial derivatives of the heat balance and the material balance with the vapour rate and temperature on the next tray. However, convergence from tray to tray is easy and any reasonable approach should be satisfactory.

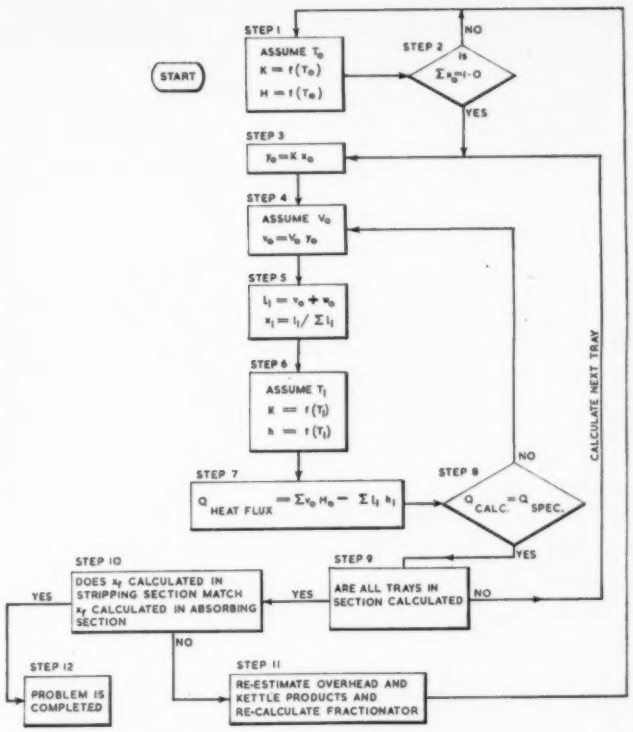
(3) The third and most difficult question involves the method of making the two ends of the fractionator mesh in such a way that the design problem is satisfied (step 11). A simple approach, widely used, assumes that the absorbing and stripping action is unchanged from pass to pass. That is to say that the concentration (x_f) of any component on the feed tray is equal to some constant (C_1) multiplied by the concentration (x_0) in the overhead product and another constant (C_2) multiplied by the concentration (x_w) in the kettle product:

$$x_f = C_1 x_0 = C_2 x_w$$

The constants C_1 and C_2 are evaluated from the previous pass while x_0 and x_w can then be calculated from the material balance.

Symbols Used

A_i = inside tube surface per ft of tube length (ft²/ft);
A_e = effective surface per ft tube length (ft²/ft);
A_{eq} = equivalent effective area of radially finned tube; (ft²/ft);
A_f = finned area per ft of tube length (ft²/ft);
A_o = outside tube area per ft of tube length (ft²/ft);
A_r = fin root area per ft of tube length (ft²/ft);
D = total moles of distillate;
D_e = effective diameter (ft);
D_{eq} = equivalent diameter of radially finned tube (ft);
F = multipass correction factor;
f = total moles of component i in feed;
g = gravitation constant (ft/h²);
H_m = mean effective fin height;
k, k_f = conductivity (subscript f for condensing film) (Btu/h ft °F);
L = length of flow path (ft);
N = number of units in series;
N_{sp} = number of shell passes;
N_{tp} = number of tube passes;
N_f = number of radial fins per in. length (l/in.);
N_t = number of tubes in shell;
p = tube layout pitch (in.);
P = flow perimeter (ft);
T_1, T_2 = hot stream temperatures in and out (°F);
t_1, t_2 = cold stream temperatures in and out (°F);
Δt_{cf} = temperature drop across the condensate film (°F);
W = total moles of kettle product;
W_c = condensate flow rate (lb/h);
α, α_o, α_i = film coefficient (subscript o for tube outside; i for tube inside) (Btu/h ft² °F);
λ = enthalpy (Btu/lb);
(cP);
μ or μ_f = viscosity (subscript f is for condensate film)
η = fin surface efficiency;
ρ or ρ_f = mass density (subscript f for condensate film).



▲ 5 *Calculation steps in tray-by-tray computer calculation of fractionators.*

$$D x_D + W x_w = f_i$$

D = total moles of distillate
W = total moles of kettle product
f = total moles of component i in feed

In using this approach, it is customary to assume negligible amounts of light components in the kettle product and heavy components in the distillate for the first pass. Thus temperatures calculated for the absorbing section will tend to be lower than real, and the temperatures calculated for the stripping will be calculated higher than real. This in turn means that the method will overestimate the volatility of light components in the stripping section and underestimate the volatility of heavy components in the absorbing section. Each pass will be closer than the preceding one, and the amount of light components in the kettle product and heavy components in the distillate will always be underestimated although the answer can be approached to any degree of accuracy needed. The changing of the overhead and bottom products necessary to obtain a solution does not guarantee that the solution obtained is exactly what was desired. For instance, the design engineer may specify trays and reflux for an estimated 98 per cent recovery at 92 per cent purity on a certain component. The method outlined will compromise on all specifications, i.e., if the reflux and trays are inadequate for the separation postulated, it will calculate operation at a somewhat poorer recovery and somewhat poorer purity than was desired. If this happens a new calculation pass must be made at a higher reflux rate or more trays or a different amount of distillate.

With respect to the solution type, the two most common problems in the petroleum industry are:

(1) The fractionator performance evaluation problem. In this problem it is desired to find the number of equilibrium steps in an operating column in order to determine its efficiency. In this case the reflux rate,

reboil rate, feed rate and composition, and split of the feed components are known.

(2) The fractionator design problem. In this problem it is desired to find the reflux rate necessary to produce a desired split of the feed with the number of equilibrium steps and feed rate and composition known. The simple convergence method above does not solve either of these problems directly. The problems must be solved as a series of complete solutions using the simple convergence. Fortunately, it is possible to programme this series of solutions into the computer.

A second difficulty in the simple convergence is that, unrestrained, it will vary the distillate quantity considerably while it is necessary to hold it constant or nearly so in order to solve the problems mentioned. A variation we have found useful is to hold the two key components (the components actually being separated) constant for two convergence passes before allowing them to change. Another variation is to prevent one of the key components from changing on any pass and hold the other key constant for the first two passes. These techniques allow the light and heavy components to approach their true values before the keys are changed. If these techniques were not used, it might not be possible to solve the problem as given.

The simple convergence discussed, while it does not readily solve basic fractionators, is not general enough for the best usage of a computer programme. It does not allow calculation of absorbers, or of absorbers and fractionators which have multiple feeds, single or multiple liquid or vapour side draws, intercoolers, or interheaters. These problems, however, are also precisely the type which short-cut solution cannot solve satisfactorily and where the computer will be most helpful. Various modifications of the basic method are required, as briefly described below.

The absorber case can be solved by treating the extremely low volatility components found in the oil as separate entities from the remainder of the components in the system in the equilibrium calculations tray to tray and in the convergence calculations used to predict new overheads and bottoms guesses.

The intercooler and interheater problems can be solved by specification of the re-entry temperature of the treated stream and use of this temperature to correct the heat flow in the column between tray-to-tray calculations at the appropriate tray.

Multiple feeds may be calculated in this way: One feed is designated the primary feed and the basic convergence uses this feed location for its mesh. The remaining feeds are introduced between tray-to-tray calculations by adjustment of the heat and material flows as required by the feed specifications.

Draw problems may be handled by a similar adjustment in heat and material flows between tray-to-tray calculations. Draws are specified by total quantity and either tray or purity of any one component. Draw problems cannot be worked with the same convergence equations used in the basic case. This is because the overall material balance for individual components is not maintained on successive passes because the quantity of each component in the draws is not known until tray-by-tray calculations have proceeded to the tray from which the draw is removed. For this reason, draw problems require convergence equations which not only lead to a feed mesh but also lead to an overall material balance on each component.

Additional variations to the basic fractionator programme will be generated within each company because of particular components, individual practices, or variation in equipment. It is profitable to permanently programme any of these which occur regularly into the general programme. Those which occur infrequently are best handled by special modification of the general programme as they arise.

(To be continued)

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Height and Design of New Chimneys

THE Air Pollution Panel of the Federation of British Industries at its meeting on November 11, 1958, appointed a Working Party to make recommendations on the height of new chimneys with particular reference to Section 10 of the Clean Air Act.

The Working Party's main recommendations, contained in a handbook which has just been published, refer to industrial boiler plants with an output of 5000-33,000 lb/hr steam at maximum continuous rating. Recommendations are also made in respect of larger plants up to an aggregate steam capacity of 450,000 lb/hr. None of the recommendations refers to washed gas effluents.

It is also recommended that an F.B.I. Working Party should make a survey early in 1963 of the conditions around new chimneys built to these recommendations to check whether any modifications to the proposals are desirable.

Copies of the handbook—*Height and Design of New Chimneys*—are obtainable from F.B.I. Print & Publications, 21 Tothill Street, London, S.W.1, price 4s. post free (excluding airmail).

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CHEMICAL PLANT SUPPLY PROBLEMS

AN informal discussion on "Delivery Difficulties in Relation to Chemical Plant Equipment" was held at Manchester on June 27 by the Institution of Chemical Engineers, North-western Branch. Short papers were presented by nine principal speakers.

MR. G. P. BALFOUR, Managing Director, Stockdale Engineering Co. Ltd., suppliers of specialized chemical plant, observed that users are very interested in the delivery times and in the maintenance of delivery promises. The chemical industry has a high rate of capital investment and an expansionist outlook, whereas, by contrast, the engineering, steel and electric motor industries in Great Britain have a cautious approach to expansion, and a similar attitude has filtered down to the shop floor. The fear of dwindling order books (most of which are filled 6-12 months in advance) leads to the promises of reductions in the length of the delivery periods for basic raw materials and for components; this is backed by such a small increase in capacity that a slight improvement in the economy causes many of these promises to be broken. In this situation, the chemical plant industry is competing with the rest of the engineering industry and, because it is composed mainly of small companies, it gets low priorities and the worst of broken promises. A remedy in this situation appears to be closer co-operation between the customer and the supplier, and it would greatly help if the customer accepted standard equipment wherever possible.

MR. F. H. COX, of Constructors John Brown, who design and buy chemical plant equipment, spoke of delivery difficulties. C.J.B. compete in the world market for contracts for the supply and erection of complete chemical plants, and their experience confirms that complete technical specifications greatly assist in quoting reliable delivery times. Delays in the delivery of stainless-steel fabricated vessels may be due to long delivery times for the supply of pressed or spun dished ends of stainless-steel plate, or for solid-drawn stainless-steel tubes; and a factor contributing to the excessive demand for stainless steel is the tendency of designers to specify stainless steel when other satisfactory materials exist. However, such alternatives as low chromium steels are not available in this country. Long delivery times for certain types of equipment have been customary for many years, and the plant manufacturing industry in this country still does not serve the chemical industry as well as do its counterparts in the U.S.A. and in other European countries. The shortages of some special items appear to be due to a lack of real competition in this country. As a result, some of the bottlenecks that have existed for many years still persist.

MR. W. H. JONES, of the A.P.V. Co. Ltd., fabricators and contractors of equipment, stated that many late deliveries are caused by over-optimistic planning; for example, the delivery times often allow little margin for contingencies; sometimes there is an unavoidable delay, with the result that all parties to the contract incur additional cost, and goodwill is lost. This situation can be avoided by consultation between supplier and customer during the planning stage, when the time-table is arranged, to enable the supplier to contribute towards the design of the process. Many users do not appreciate that delivery times may have to be extended by design changes made during the progress of a contract. Another point worthy of observance is for contractors responsible for overall planning to allow ample time for the approval of material specifications and working drawings, and equally useful would be for suppliers of some special materials such as stainless steels to increase their production and reduce their delivery times. The delivery times of equipment should depend upon the clarification of outstanding design features that affect the commencement of engineering work and the ordering of material, and a point for suppliers is that they could well be more selective in the work which they offer, and more prompt in notifying the customer of increased delivery times. Further, in Mr. Jones' opinion, British suppliers take too long in producing a quotation from an enquiry.

MR. D. J. A. MANSELL, of Worthington Simpson, the pump makers, detailed the basic information required to select a pump. He suggested that standard units should be ordered if possible, because the use of standard materials for pump construction can reduce the delivery time. Materials suitable for tanks, reaction vessels and pipes are not necessarily suitable for pumps. Tests are made by pump manufacturers to determine a material suitable for handling an unknown liquid and it would benefit customers if they sought a manufacturer's recommendation. Pumps made of special materials incur a prolonged delivery time and are expensive because the materials are not readily available.

A recent survey covering about a thousand different corrosive liquids at various temperatures and concentrations revealed that 92 per cent of them could be handled by pumps constructed of either iron, gunmetal or 18/8/3 stainless steel; the majority of the remainder could be handled by proprietary materials, or by nickel-base alloys, and only 0.3 per cent required a specialized material.

MR. D. I. ROBERTSON, of J. R. McKellar (Alloys) Ltd., manufacturers of castings in stainless steel and special alloys, commented that castings specified by the B.S.I. were not ordered and used as often as they should be. The lack of standardization and the enormous variety in specifications quoted result in a lot of time being wasted at a foundry to find exactly what the customer needs. Foundries should be consulted during the design of a plant, and they need a reasonable time to make a good casting with a minimum of rejects. The proportion of rejects increases considerably when casting manufacture is speeded up.

A point made by MR. F. E. VARLOW, Managing Director, Audco Ltd., manufacturers of valves for the chemical and petroleum industries, was that changes in customer stocking policy or supplier delivery can be misinterpreted as leading to a slump or boom; consultations with customers would prevent such wrong assessments that cause either the supplier or the customer to hold excessive stocks. On project work in the chemical industry, valves are usually the last item to be considered; consequently short delivery times for them are expected. The customer should be informed about the varying delivery times for different products, and he should plan his orders so as to have a satisfactory supply. Suppliers of components should study the market and make a range of standard products to supply it; they must then be prepared to change their designs from time to time to keep up

to date, and customers must buy the standard articles which can often satisfactorily replace the special products.

MR. V. J. OSOLA, of Lankro Chemicals Ltd., a medium-sized manufacturing company of intermediate chemicals which designs and constructs its plants, gave the views of a chemical plant user, and forthrightly reminded the suppliers of their obligations. Generally, only a few months are available for a project to go through the stages of pilot-plant design, full-scale commission and production. The customer can help the supplier by advance orders for long delivery materials, by paying reasonable prices for stockist delivery service, by giving a complete specification including inspection and insurance, by not inviting competitive tenders unnecessarily, by accepting near alternatives for specialized plant, by indicating delivery priorities and by ordering spare parts when ordering the plant. Suppliers should take the utmost care in quoting a delivery date, they should circulate up-to-date stock lists, obtain the firm approval of their production departments before they quote a delivery date, and quote approximate delivery dates subject to review immediately the order is booked. A broken delivery date may cost the customer far more than it would have cost the supplier to meet the original delivery date. Some manufacturers sell pipe and tube in special materials, and a customer has difficulties in finding other supplies of flanges and fittings. Spare parts should be available at district sales offices for quick distribution in emergencies.

MR. J. N. ROSS, of Enamelled Metal Products Ltd., dealt with the production of glass-lined steel where the glass is put in compression and the steel in tension. Successive coats of glass are sprayed on to the steel and the vessel is heated in a furnace after each spray of glass. A special low-carbon steel is used which is obtained from only a few suppliers. Cracks and holes in the glass are invariably formed, and these are plugged by Hastelloy or Tantalum. Some customers feel they are getting an inferior product, but this is standard procedure.

MR. A. H. ISAACS, of Foxboro-Yoxall Ltd., remarked on instrumentation for medium and small size plants. He claimed that deliveries had greatly improved in the last four years. Instruments are complex, made of high quality material, and the rapid evolution in the equipment makes short delivery times difficult. Because the instruments on a plant are installed after the plant has been constructed, there is a tendency for complete specifications to arrive late, causing delays in deliveries and installation. Control valves require an early specification and this must not be subsequently changed. A recent survey showed that 50 per cent of total communications received related to modifications and changes in the original specification.

It would appear from the above discussion that there is plenty of scope for improving the relationships between supplier and customer. Those directly concerned with the problem of getting a job done effectively, on time and with a minimum of frustration are advised to improve the planning of their projects, to seek greater co-operation from suppliers who are only too happy to oblige, to consult them more frequently, and to satisfy their requests for better specifications and greater standardization more often.

However, when this aspect of the problem is settled to the satisfaction of all concerned, there is some doubt as to whether material will flow very much faster than at present, whether plants will be erected very much sooner, or whether the products will become more competitive on the world markets.

A major cause of this problem is the shortage of basic raw materials such as steel. The order books of primary producers are filled 6-12 months in advance, yet there is no sign of planning to meet this demand. It seems a justifiable complaint that by restricting the activities of British chemical plant and equipment manufacturers, the primary producers are frustrating the efforts of an export-conscious industry at a time when increased exports are highly desirable.

First European Symposium on "Size Reduction"

THIS will be held from 10 to 13 April, 1962, in Frankfurt (Main), Germany. It is organized by the Verfahrenstechnische Gesellschaft (VTG) im Verein Deutscher Ingenieure and the DECHEMA Deutsche Gesellschaft fur chemisches Apparatewesen, Frankfurt (Main). All professional men engaged in technical developments in size reduction are invited to take part.

Three groups of themes will be covered:

Group A: Physical and theoretical principles.

Group B: Principles and recent developments in machines.

Group C: Application techniques.

Three days will be devoted to the lectures, so that no parallel sessions will be required. The languages used will be English, French and German.

Lectures are classified as principal lectures and short papers. There will be four to five principal lectures and about twenty short papers. Special invitations are being issued in connection with the principal lectures.

The intention to read a paper on new and unpublished work, accompanied by the proposed title and a short summary, should be communicated as soon as possible to the Secretariat: Verfahrenstechnische Gesellschaft, Frankfurt (Main) 7, Rheingau-Allee 25.

Authors will then be asked to make a binding application to present a paper before 30 September. The final manuscript, ready for printing, including all illustrations and a short summary should be sent before 15 December, 1961. The short papers, lasting from 20 to 25 minutes, may be selected from the following fields:

Group A: Physical and theoretical basic principles of size reduction:

(a) Physics of fracture processes.
(b) Size reduction of individual particles.
(c) Collective and mechanical size reduction.

Group B: Basic principles and recent developments of size reduction machines:

(a) Stress applied between two surfaces, including wet grinding with low viscosity media, in size reduction machines.
(b) Stress applied by impact in gaseous media: impact crushers, hammer mills, impact fine size reduction machines, disintegrators, jet mills.
(c) Stress applied by the surrounding medium: roller, cone, disk and attrition mills; drum, impact, planetary and sand mills; kneaders, homogenizers and colloid mills.

Group C: Application techniques, size reduction of certain substances:

(a) Survey of materials from the point of view of their behaviour during size reduction.
(b) Size reduction of hard substances; selective size reduction.
(c) Size reduction of soft to medium hard inorganic substances; selective size reduction, drying/grinding.
(d) Size reduction of heat-sensitive substances.
(e) Size reduction of agglomerates.
(f) Disintegration and size reduction of fibrous substances.

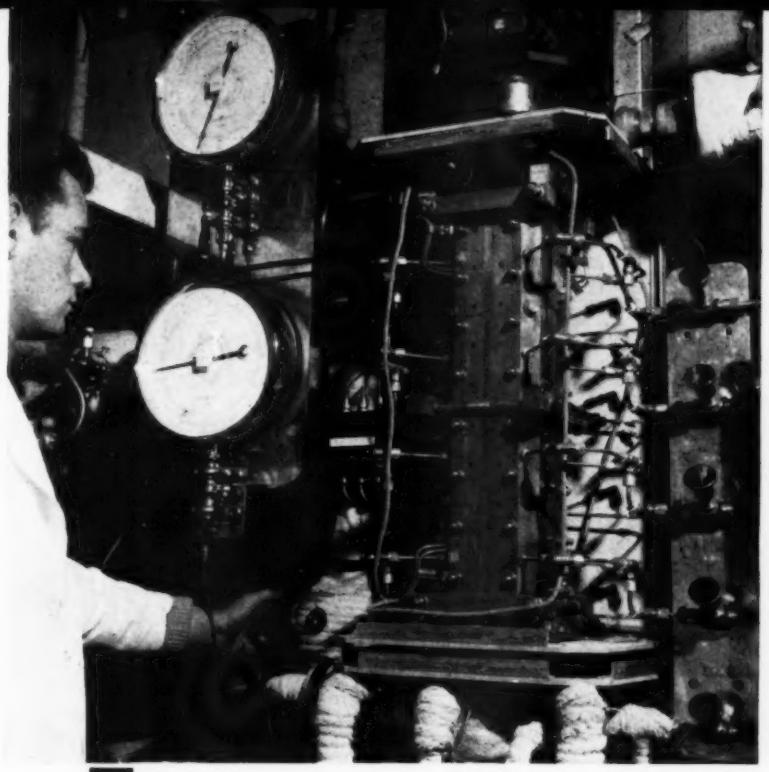


Fig. 1. A special unit designed to simulate effects in rod cluster fuel elements operating with steam/water mixtures.

AN INTRODUCTION TO HARWELL

THE main function of the Research Group at Harwell is to carry out fundamental and a certain amount of applied research in the various civil applications of nuclear energy, and in this connection close collaboration is maintained with all the groups within the Authority: Aldermaston, Winfrith, Wantage, Culham, etc.

The organizational changes which have recently taken place within the Authority have brought Harwell into a new phase of its development; the policy now being to keep the establishment in a state of flux and dynamic equilibrium, and to avoid it becoming too settled, with a fixed complement.

One of Harwell's greatest needs is people with ideas, fresh minds and initiative, as well as people with experience in nuclear problems. Success brings about change and change brings new problems, different from the old and often requiring a new approach. The organization must therefore be flexible, and the people in it versatile enough to move from one type of problem to another.

Harwell views the extension of the C.E.G.B. programme of nuclear power stations as providing a better economic balance between research, development and design. This should reduce many uncertain factors, and save hundreds of thousands of pounds in the final cost of a civil reactor.

At present the staff at Harwell is limited numerically and in certain areas is hard-pressed. The establishment has the problem of finding the particular kinds of people needed to replace those who have moved to other establishments within the Authority. The determination of priorities is an important aspect of the work, and collaborative programmes exist with laboratories in the U.S.A., Canada and Europe.

The following is a very brief account of some of the work carried out at Harwell which would be of interest to readers of this journal.

Two-phase Flow and Heat Transfer

The present U.K. power programme is based on gas-cooled graphite-moderated reactors. However, the water-cooled and particularly the boiling-water-cooled systems are attractive for future reactors. The advantages of such systems are: the ability to generate steam within the reactor, and the extremely high rate with which steam/water mixtures remove heat from reactor elements. Chemical engineering research at Harwell relates to heat transfer and fluid flow in variants of boiling systems, particularly in climbing film flow.

The behaviour of a liquid being boiled in a tube is complex. Four flow patterns are obtained with steam/water mixtures in upward vertical flow through tubes. As the proportion of steam increases, at constant water rate, the patterns change from bubble flow to plug flow to churn flow to climbing film flow. Ordinary boiling-water reactors are designed to operate primarily in the bubble region, but other conditions will prevail if steam flow increases or the water flow decreases. The spray-cooled reactor normally operates in the climbing film region.

Fuel element designs favoured for high output are bundles of rods or plates, with the coolant mixture flowing in the interstices. Little is known about the flow of a two-phase mixture in such a system, except that climbing films can form on all the rod surfaces. Equipment is being constructed to study this in full-scale assemblies with water and air at elevated pressure. An approximation is provided by a rod in the centre of a tube, and this has been employed for the heat-transfer studies.

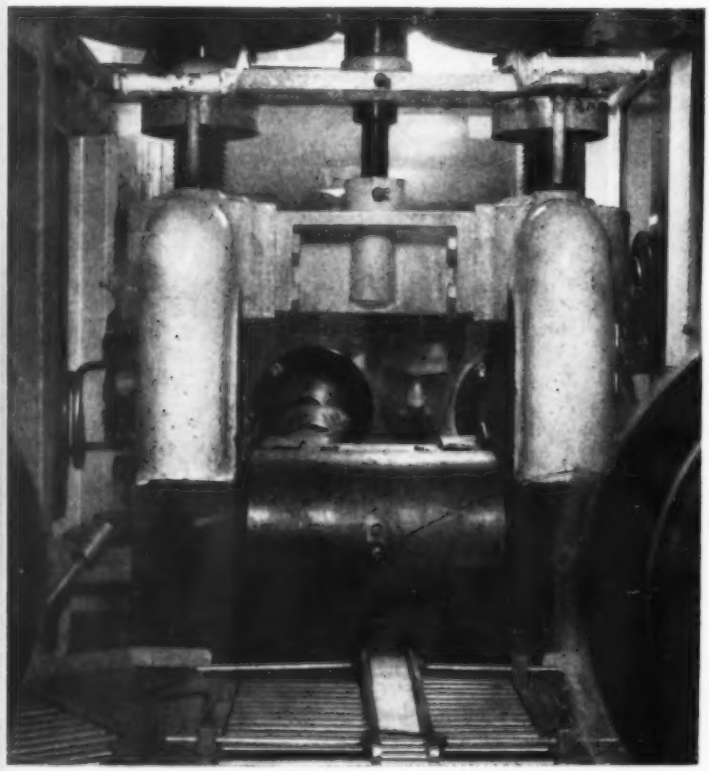
A principal object of this heat-transfer work is to determine the maximum rate of heat removal possible in such systems. Beyond a certain rate the water film is destroyed, and the much lower heat transfer through the steam causes the fuel element temperature to rise very rapidly, which may lead to melting and "burn-out". Reactors must be designed so that they cannot reach this condition.

Data from all these experiments are recorded and fed directly to a "Mercury" computer. This gives a high return in terms of experimental results for investment in expensive equipment, and considerably accelerates the rate of research.

The Recovery of Protactinium from Ore Residues

Protactinium occurs naturally as the isotope ^{231}Pa (half life 34,000 years) in the decay chain of uranium 235. The maximum posible concentration of this isotope is 0.34 part $^{231}Pa/10^6$ parts of natural uranium. The richest source of uranium contains 1 part $^{231}Pa/10^7$ parts of ore, and this element had never been available in greater than milligram quantities.

The first extraction in this country of uranium from ores was done at Springfields by the Industrial Group of the A.E.A. One of the residues which were accumulated from the process, known as "ethereal sludge", amounted to 60 tons, and contained 20 tons of uranium, about 160 gpm of protactinium and varying quantities of other elements. A process was developed to recover both uranium and protactinium from this residue, and 125 gm of protactinium were recovered having a chemical purity of 99.9 per cent. This protactinium will be the world's only stock of this element for many years to come, since ores known to be rich in uranium are now very scarce and new methods of uranium extraction, whilst more efficient for uranium recovery, do not give rise to residues from which the recovery of protactinium is economical.



Decontamination of Radioactive Effluent

(1) Ion Exchange Process

In treating radioactive effluent by ion exchange, two factors must be considered: (a) the ion exchangers must decontaminate the effluent effectively so that the treated water may be dispersed; (b) the waste produced by the process must be very small so that it can be conveniently stored.

Organic ion exchange resins are costly and must be regenerated. This normally produces large volumes of highly active regenerant liquors. A two-stage regeneration technique, which considerably reduces regenerant volume, has been developed recently.

This ion exchange plant designed for 500-1000 gph of medium-level active effluent, consists of four columns which contain, alternately, cation and anion exchange resins. In the first column inactive and radioactive cations are exchanged for H^+ ions. In the second column inactive and radioactive anions are exchanged for OH^- ions. These combine with the H^+ ions, liberated from the first column, to form water. Thus the first stage of the plant considerably reduces the radioactivity and replaces it by water. The second stage works in an identical manner and affects the final decontamination.

(2) Two-stage Chemical Precipitation, Ion-Exchange Process

This plant consists of sludge blanket precipitators followed by ion-exchange columns.

The raw effluent is mixed with chemicals in a tank and then flows through either a circular precipitator or a pulsator unit, in both of which a sludge blanket is maintained at a suitable height within the apparatus. All the incoming effluent passes through this blanket, which promotes particle growth and also acts as a filter. As the sludge blanket rises above the height of balance, a proportion of the sludge is periodically removed to maintain the blanket at a constant depth and density. Decontamination obtained by chemical treatment is not very high and the effluent is further treated through ion-exchange columns.

Phosphate Treatment

Precipitation with phosphate is satisfactory for an effluent containing a variety of radioactive isotopes. Optimum conditions are such that the ratio PO_4^{3-}/Ca^{2+} is about 1.6 with a minimum dosage of 50 mg/litre Ca^{2+}. If this amount of Ca^{2+} is not already present in the raw effluent, it is added as $CaCl_2$ or $Ca(NO_3)_2$. Also, a denser precipitate is formed if a ferric or ferrous salt (40 mg/litre Fe^{2+} or Fe^{3+}) is added as a conditioning agent.

This calcium-iron-phosphate precipitation treatment removes about 99 per cent of the alpha-emitters and about 89 per cent of the mixed beta-omitters. The residual activity is largely due to cæsium with traces of strontium and ruthenium.

To remove this cæsium and possibly the strontium and ruthenium, two ion-exchange columns have been incorporated into the plant. These are packed with crude vermiculite, a cheap, expendable, naturally occurring ion-exchange material, which is efficient and needs no further treatment before disposal. The effluent from the vermiculite columns contains virtually no alpha-omitters and 0.3-0.5 per cent of the original beta-emitters.

Phosphate-ferrocyanide Treatment

Since the calcium-iron-phosphate treatment is poor for

Fig. 2. Typical arrangement for an ion exchange process.

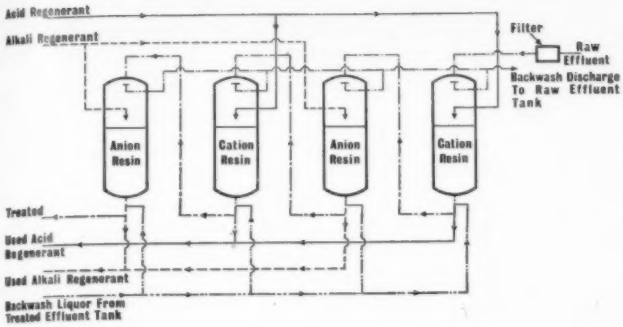


Fig. 3. Rolling of cement fuel plates containing plutonium.

cæsium removal, a high load will fall on the vermiculite columns if the raw effluent is high in radio-cæsium. More recently, therefore, this process has been modified to treat effluents high in radio-cæsium.

Optimum conditions are such that the PO_4^{3-}/Ca^{2+} ratio is about 1.6, with a minimum of 50 mg/litre Ca^{2+}, 25 mg/litre Cu^{2+}, 16 mg/litre Fe^{2+} and 40 mg/litre $Fe(CN)_6^{4-}$. About 99 per cent of the alpha-emitters and 95 per cent of beta-emitters are removed and the residual activity contains virtually no cæsium.

The effluent from the vermiculite columns contains virtually no alpha-emitters and approximately 0.5 per cent of the original beta-emitters. A third stage, which may be added to both these processes, consists in treating the effluent through an electrolytic deionization cell to further reduce the activity level. Alternatively, the deionization cell may replace the ion-exchange columns as a second stage after chemical treatment.

(3) Electrodeionization through a Packed Bed

In this process a solution passes through a bed of mixed exchanger material, which is held between two membranes. One of these is permeable to cations, the other to anions. A current passes at right angles to the liquid flow such that both cations and anions are removed from the mixed bed through the membranes. Under these conditions the mixed bed is converted partly to the H^+ and OH^- forms.

The transfer of ions proceeds in two stages. In the first stage, ions are transferred from the solution to the ion exchanger particles by ion exchange processes; the cations are exchanged for H^+, the anions for OH^-. As H^+ and OH^- ions are removed from the equilibrium by formation of water, this process of exchange adsorption is practically irreversible. For dilute solutions the process is controlled by diffusion in the aqueous phase.

In the second stage, the ions are transported inside the exchanger particles by the electric current flowing through the exchanger bed, until they reach the membrane walls of the cell through which they leave the compartment and pass into the concentrate stream. In general, the better the current utilization, the slower the diffusion transport and the larger the equipment, and vice versa. Optimum conditions have thus to be determined for each deionization.

Chemistry and Metallurgy of Nuclear Fuels

(1) Cermet Fuels for Fast Reactors

A cermet is a dispersion of ceramic particles within a metal matrix, and it combines the desirable irradiation behaviour of ceramic fuels with the high thermal conductivity and mechanical strength of metals. For fabrication reasons, ceramic particles should preferably be spherical. Fabrication techniques will depend largely on the ceramic content: conventional metallurgical techniques may be employed at low content, but at higher contents powder metallurgy methods may be used. Powder is pressed into small pellets which are spherodized by vibrating them for some hours on a curved track coated with carborundum. When the pellets are completely rounded, they are fired in a hydrogen atmosphere at 160°C to produce the finished granules.

(2) Plutonium in Cermet Fuels

Plutonium is, in theory, the most suitable fissile material for a fast reactor. To reduce the heat rating of the fuel to an acceptable level, plutonium is incorporated into a uranium-based alloy, ceramic or cermet. In a cermet, plutonium is incorporated in the ceramic phase together with the corresponding uranium compound, PuO_2-UO_2 or PuC-UC.

(3) PuC-UC Fuel Fabrication

The mixed monocarbides of plutonium and uranium are perhaps more suitable as fast reactor fuels than UO_2. The thermal conductivity of UC is much greater than that of UO_2, so that fuel pieces of large cross-section can be irradiated under fast reactor conditions without their centre temperature becoming excessively high.

Investigations into a variety of fabrication processes for carbide fuels will include the sintering of carbide solid solutions prepared from mixed PuO_2 and UO_2; the sintering of blended UC and PuC and the preparation of (UPu)C by the reaction of U+Pu+C; and the sintering behaviour of crushed arc melted solid solutions.

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New Data Centre

IBM'S new Data Centre, now open in London,* offers commerce, industry and research direct access to a computing centre as powerful as any in Europe.

The Data Centre is a customer usage operation. IBM specialists will provide the user with the necessary instructions, advice and assistance in all aspects of programming and operating the equipment, and the user pays only for the machine time which he actually uses. The machines are installed and maintained by IBM and the customer keeps in his own hands the programming and processing of his own jobs.

* IBM Data Centre, 58/62 Newman Street, London, W.1.

Computers available are the IBM 7090 system, highly versatile and the most powerful computer in general use today, and an IBM 1401 system which is a smaller scale computer used for the preparation of input tapes from cards and for the conversion of output tapes to punched cards or to printed documents.

Amongst IBM's facilities is a library of programmes and sub-routines which can save a customer a lot of programming time. From time to time, the Data Centre holds management appreciation seminars which last a day or two, and special programming courses which last one to four weeks.

ACHEMA 1961

The concluding section of this account reviews a number of new designs of fine particle-making equipment, mixing machinery, particularly for incorporating liquids in solids, filters and centrifuges. Instruments and materials of construction are also briefly considered

Mixing Machinery

Additional equipment for the low-power-consuming, rapid-action, twin- or single-screw Nauta mixer was a device for mixing liquids with solids. If required, this will inject very small liquid quantities of the order of 1 per cent of the total mass of solids present in the mixer. The device is fitted to the apex of one of the inverted cones in close proximity to the lower end of the corresponding agitating screw. The liquid is introduced through a hollow high-speed rotating shaft to which is attached an atomizing head, and the finely divided liquid is projected into a highly agitated and well-broken-up mass and is not merely spread upon adjacent particles. This and the action of small beater arms attached to the rotating shaft prevent the formation of lumps.

For duties requiring the precise addition of a binding agent to a solid mass, typified by the preparation of mastic asphalt, Wibau-Vertrieb Matthias put forward a trough-type mixer with an arrangement of blades which, in addition to supplying an intensive mixing action, also sets up a suspension zone above the blades. It is in this zone that finely divided liquids such as binding agents are added to the solid batch, and the time required for complete incorporation is usually less than a minute.

In the field of fluid mixing equipment, many varied designs were on view. Thus, among high-shear impeller-type machinery was a new model from Morehouse International capable of mixing fluids with viscosities in excess of 50,000 cp. A feature of these machines (the Cowles dissolver) is the improved power transmission which allows more than 90 per cent of the motor hp to be applied to the mix, even at the lowest speeds provided by the stepless transmission. Correct estimation of motor size and therefore saving in power and first cost are other benefits of the design.

Turbine-type mixers were also very numerous. Thus, for liquid-liquid, liquid-solid and gas-liquid processing Erkato-Normrührer displayed equipment representative of their very wide range. This includes radial and open turbines, double-deck radial turbines of large height to diameter ratio, all supplied in diameters up to 1 m. Standardized open or closed vessels in which these agitators can operate and a variety of shaft sealing arrangements are available.

They are also supplied by the company in capacities up to 100 m^3 and, in addition, a range of shaft sealing arrangements are available, one of the most noteworthy being a high-pressure seal. This consists of two mechanical sliding face elements and a labyrinth seal fitted adjacent to the vessel cover. The sliding face seals are in a water-cooled enclosure in the sealing fluid. The enclosure is connected to a small cylinder closed at both ends and containing a sliding piston fitted with "O" rings with a rod projecting through the upper end. The lower end is connected to the vapour space of the vessel so that the pressure around the seal is balanced. The sealing fluid is circulated by pump and passed through a separate heat exchanger for cooling purposes, the pump being driven by independent motor or by belt drive off the agitator shaft.

In the drum filter agitator shown by Krauss Maffei (Fig. 27, page 556 of the August issue of this journal) agitation of pulp is obtained by the pulsations brought about by the alternate drawing up and releasing of liquid from a system of vertical tubes which dip beneath the pulp level in the trough. The action is obtained quite simply by the cyclic application and release of vacuum to the dip-pipe manifold.

Another type of mixer, also capable of mixing liquids with solids and of performing other intensive mixing tasks as well as particle reduction, was shown by Eirich. The principle of this machine was illustrated in Fig. 7; three movements are provided: that of the rotating pan, of counter-rotating mixing tools and of the high-speed rotary agitator, the latter consisting of a circular frame fitted with vertical adjustable pins. A feature of the operation is a speed differential between periphery and pan centre, which subjects the material beneath the rollers to a thorough stretching and shearing action; the action of the high-speed agitator is to disintegrate lumps and nodules. Capacities are up to 54 cu ft and the machine may be totally enclosed.

High-capacity Filter with Self-discharge of Cake

In addition to the filters described in the first part of this article, three others at least are of interest. The first is manufactured by Schenk Filterbau G.m.b.H. and is available in either vertical or horizontal types. It consists of a hollow central shaft to which is attached a system of circular filter elements. These are fitted within a stainless-steel pressure vessel and employ a stainless-steel woven mesh as the filter medium. The filtrate is forced through ports in the hollow shaft, which is itself connected to a motor-gear unit. When a filtration is completed, the shaft is rotated and the cake discharged through the centrifuging action. In the case of the vertical model, the plates have their upper surfaces fitted with the stainless-steel mesh; in the case of the horizontal filter both surfaces are for filtration. Filtering surfaces are up to 30 m^2 for the vertical filter and up to 60 m^2 for the horizontal filter.

A second filter, which can only be briefly mentioned here, makes use of a system of woven bags supported on a rectangular frame spanned by a series of spring-loaded chains. The whole assembly is enclosed in a pressurized compartment and the various elements are quickly detachable to allow removal of cake. This equipment, made by Scheibler, Wuppertal-E., is offered in filter surfaces up to 150 m^2.

The third filter was the most recent Sparkler enclosed pressure filter which is particularly suitable for handling toxic materials or for maintaining sterile conditions. This is a batch machine with horizontal plates fitted within a rotatable frame; each plate connection is fitted with a sight glass to give a check on clarity. The cake can be discharged automatically without opening the cover; by rotating the plates to a vertical position and applying pressure with the plates the cake discharges through a screw conveyor fitted below the plate assembly. Cake thickness can be

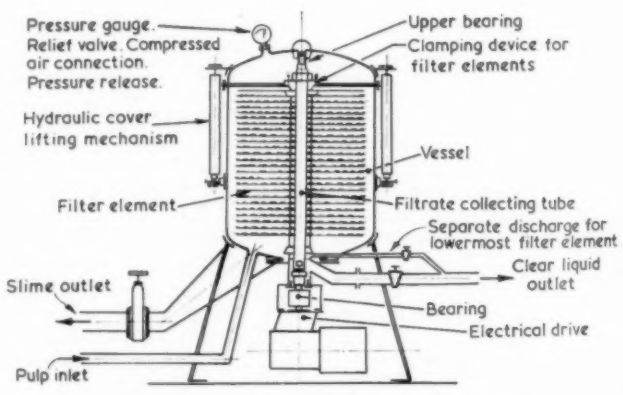

Fig. 31. The Schenk vertical centrifugal filter with self-operating slime discharge.

built up as required and is limited only by pressure resistance. Capacities are up to 40 m² and the outer shell can be jacketed for heat-transfer fluids.

Thin Film Reactor

To the brief description of the Techemos-Hibernia reactor (Fig. 32) published in the first part of this article the following additional information can now be given. In the first place the field of the apparatus is continuous heterogeneous reactions where one phase at least is a liquid such as liquid-liquid, solid-liquid, gas-liquid reactions; the maximum working pressure can be as high as 500 atm., the drive rpm are infinitely variable and the motor is reversible. As a result of this latter feature, the two phases can be made to flow either co- or counter-currentwise, and with the wobble-type agitator the inclination of the blading to the shaft can be changed during operation, thus allowing the reaction volume to be adjusted. The design offers wide flexibility in operation, and close control of such operating parameters as temperature and residence time.

Materials of Construction

A great deal could be written about the numerous constructions in metallic and non-metallic materials. Many examples were shown of titanium and tantalum applications, in particular for heat exchangers, and also valves, and pumps, and such non-metallic materials as glass, chemical stoneware, porcelain and graphite were, if anything, even more prominent, including processing vessels, mass transfer equipment, valves and pumps—including metering pumps and pumps for vacuum. Some of the more spectacular exhibits were constructed from glass-fibre-reinforced polyester and included processing vessels, storage tanks, cooling tower bodies and process pipelines capable of withstanding quite high pressures, and one firm, Dorr-Oliver, showed, as a useful alternative to stainless-steel or rubber-covered construction, a vacuum drum-drier constructed in this material.

Fluorocarbon materials were numerous, especially for fluid flow equipment for corrosive duties. Martin Merkel K.G., for example, showed extruded PTFE tubes and hoses with flanged ends and an important innovation in tubing of this material reinforced by metallic coating applied by a galvanizing process. The tubing is suitably thus made for vacuum and pressure applications.

A material which has already been introduced into Britain but with minor publicity was shown by N.V. Hercules Powder Co., The Hague, Netherlands. This material, introduced into the U.S.A. in 1958, is a chlorinated polyether known commercially as Penton, and can be used as either a constructional or coating material for corrosion-resisting equipment. Properties include exceptional dimensional stability, low water absorption and resistance to temperatures up to 135°C; it is supplied as sheet, precision mouldings, or as a powder for spraying. A single pass of a powder dispersion will provide pinhole-free coatings up to 0.5 mm thick and a number of techniques for this purpose are available, such as those of the Pfaudler Co. and Knapsack-Griesheim A.G.

Enamelled Metal Vessels

Besides the impressive assortment of glass-lined equipment shown by such firms as Schwelmer Eisenwerk, a number of other novelties in this field were noted. The first was a tiltable reactor shown by Nikex, the tilting being performed by a manually-operated hydraulic device neatly installed within the casing carrying the vessel trunnions. The equipment can be provided with a variety of standardized cover connections and types of agitator. The equipment is suitable for temperatures up to 165°C and for working pressures of 6 atm in the vessel proper and 6 atm in the jacket, and capacities are in the range 200-2000 litres. An open tilting pan, with or without agitators, is also available from the same organization.

The Swiss firm of Von Roll Eisenwerk Klus, Klus, Switzerland, showed two vessels—a 400-litre capacity unit with an infinitely variable drive controlled from a console, its operation a source of amusement to many a visitor, and a larger vessel of 2500 litres which was noteworthy in providing an easily-replaceable inner vessel. Its flange is clamped between cover and jacket by means of the company's own screw clamping device, an arrangement which allows the inner vessel to be replaced without dismantling the jacket or removing its insulation.

Fine Particle Machinery

Illustrated in the first part of this article (Fig. 22) a new submicron mill attracted considerable attention. The Micromolitor, made by Eickhoff, obtains its comminuting effect by creating millions of vortices per second. This is achieved by the high-speed rotation of a number of cylindrical elements, with perforated honeycomb walls, attached radially to a central rotating shaft, the peripheral speed at the outer edges of the elements being 80-100 m/s. A stator is fixed to the cylindrical shell of the mill and is inserted between the front edges of the rotating cylinders.

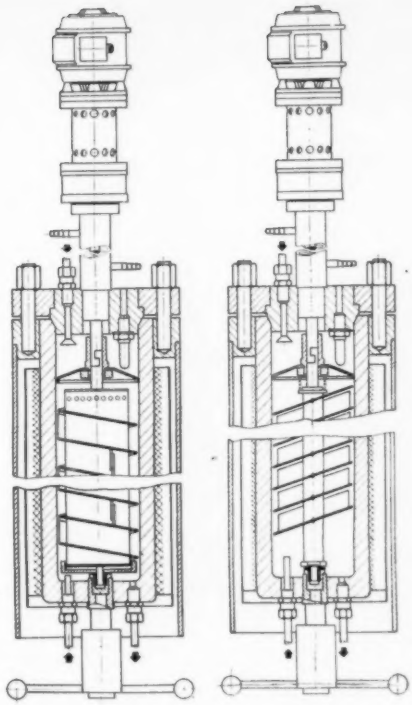

Fig. 32. Two types of thin-film reactor of Techemos-Hibernia design which make use of magnetic couplings—(a) hollow screw type; (b) wobble plate type. The agitators rotate at 5000 rpm. Maximum operating pressure and temperature 350 atm and 300°C respectively.

Another new design deriving its grinding effect from high-frequency turbulence was the Asima-Mikro mill shown by Arthur Simon. It consists of a casing provided with vertical grooves and ribs surrounding a high-speed rotor, the intervening space forming a narrow grinding gap, the zone of intensive turbulence. A number of such gaps are provided in layers. Two variations of the design were shown, one with self-contained fan for producing the stream of carrier air, and a larger model with separate fan. The effectiveness of the machine for producing micron size particles of soft materials could be judged from a display of samples of different materials produced by this mill.

Process Control Equipment

One of the features of the very interesting Hartmann & Braun stand was the use of schematic diagrams illustrating the application of many of their instruments to specific processes. A case in point was a liquefied air distillation process for the separation of oxygen, nitrogen and argon equipped with analysis instruments to help to obtain optimum operating conditions. For example, for the control of argon purity two types of instrument are specified, a thermal conductivity gas analyser capable of metering hydrogen in the range of 0-2 per cent and an electrochemical oxygen instrument with a range of 0-20 ppm O_2. Similar instruments are applied for the purity of the nitrogen stream, while for the oxygen streams electromagnetic instruments with narrow span oxygen ranges are specified. For optimizing control of chemical processes the same company, in collaboration with Schoppe & Faeser G.m.b.H., introduced an apparatus known as the Liberatol 500. This device can collect data, process them statistically or otherwise to provide a deeper understanding of a given process, apart from providing a substantial automization and optimizing function.

A contactless process signal system was one of the many notables among the Siemens exhibit; it can accept a number of electrical signals and convert them to a suitable acoustic and/or optical warning when the combined primary signals indicate the onset of a dangerous situation. This prepares the way to contactless automatic control systems.

Abstracts

GROUP A—FLUID DYNAMICS

Analysis of Annular Two-phase Flow: Application of the Dukler Analyses to Vertical Upward Flow in a Tube*

The most advanced analytical treatment of annular two-phase flow is that of Dukler, who considered downward co-current flow only. The present report describes its adaptation to upward co-current flow, both fluid dynamics and heat transfer being considered. Schematic diagrams have been prepared which illustrate the place of the analysis in calculations on two-phase flow, and a substantial amount of tabular material is presented which is abstracted from the numerical solutions obtained on the Harwell "Mercury" computer.

G. F. Hewitt, U.K.A.E.A. Report AERE-R.3680. Available from H.M.S.O., 5s. 6d. net.

Evaluation of the Terminal Velocity of Droplets and the Rising Velocity of Bubbles

A diagram is presented for evaluation of the steady rising or falling velocity of spheres in media of any density, in the use of which the previously necessary approximation method is avoided. The comparison of the calculated curves with those obtained experimentally shows simultaneously in which ranges the resistance indexes of droplets and bubbles are in agreement with those for spheres of the same volume.

P. Grassman and A. Reinhart, *Chemie Ing. Tech.*, 1961, **33**, 348.

Contribution to the Theory of Hydraulic Cyclones and Data on Performance of Small-diameter Cyclones—Part III

Data are presented for poly-disperse feed and mono-disperse feed techniques. In PDF experiments, thoria of 5-50 micron range was circulated at 19-22°C as an aqueous slurry in concentrations of 1-10 gm/litre. Reproducibility was poor and experimental inaccuracies were unacceptable. In MDF experiments, fractions of closely sized glass particles were used in a non-circulatory system. In general, small-diameter cyclones behave as the larger ones, and data obtained from large cyclones can be applied to them.

D. Bradley, U.K.A.E.A. Research Group, Harwell. Report No. AERE-R.3146. Available from H.M.S.O., 8s. net.

An Investigation of Laws Governing the Spouting of Coarse Particles

The relationships between the variables involved in the spouting of coarse particles are considered. The four categories of variables are dependent on (a) gas and particle properties; (b) column geometry; (c) bed depth; (d) position within bed. 6 refs.

H. A. Becker, *Chem. Eng. Sci.*, 1961, **XIII** (4), 245-62.

Studies on Axial Mixing of Particles in Moving Beds

To design an apparatus in which a moving bed is used, it is important to know the behaviour of the particles in the bed, particularly when holding time requires strict control. Experiments were carried out to determine the degree of mixing of steel balls, silica alumina balls and Soma sand particles in moving beds, using tracer particles. The tracer was added at the top of the bed and its concentration measured at the bottom. Curves were plotted of the concentration of the tracer at the bottom of the bed, and coefficients of axial mixing were calculated from these curves.

A difference was observed between the velocity of the particles forming a monolayer on the tube wall, and that of the particles in the bed core.

S. Yagai *et al.*, *Chem. Eng., Japan*, 1961, **25** (6), 469-75.

Solids Mixing in Fluidized Beds

Studies were made of the residence time of glass beads fluidized with air. Aspect ratio (L/D of fluidized bed) has a very marked effect on the flow pattern; the tendency of solids to plug flow increases with increased aspect ratio. Very high solids throughputs also cause plug flow. Increase in air rate improves mixing.

S. R. Tailby and M. A. T. Cocquerel, *Trans. Inst. Ch. E.*, 1961, **39** (3), 195-200.

* Author's abstract.

The Behaviour of 12-in.-diameter Gas-fluidized Beds

In experiments with a 12-in.-dia. glass-walled column measurements were made of pressure drop across bed, bed expansion, bubble diameter, and vibration of column, over a range of the following parameters: particle density, particle size, initial height of bed, distributor design and air velocity.

The effects of the parameters were complex and interrelated, and the results are of little use in providing design data. The most consistent conclusion is that a porous plate distributor gives better fluidization than either discrete holes or a single cone.

It is doubtful if pilot-plant studies can be helpful in predicting the behaviour of fluidized beds.

P. N. Rowe and W. M. Stapleton, *Trans. Inst. Ch. E.*, 1961, **39** (3), 181-7.

A Study of the Hold-up of the Dispersed Phase in a Pulse Column

The conductimetric method described here permits the determination of hold-up between two plates of a pulsation column without interrupting its operation. Results show that hold-up varies along the column, and this method permits to observe this variation when the flow-rates or the pulse-frequency are changed. It will perhaps be possible to partly explain the results obtained by assuming a diffusional mechanism for the flow of liquid-liquid dispersions. 6 refs.

F. Defives and G. Schneider, *Génie Chim.*, 1961, **85** (S6), 246-50.

Drag Forces in a Hydraulic Model of a Fluidized Bed—Part II

A regular array of ½-in. spheres was placed in a water stream. The ratio of the drag on a sphere in the array to that of a sphere in isolation at the same fluid velocity varied inversely as the separating distance in the array. Applied to fluidized beds, these results indicate that small local changes in particle concentration are unstable, except when particles are separated by tens of sphere diameters. The minimum fluidization velocity predicted from these results agrees well with experimental observation. 5 refs.

P. N. Rowe, *Trans. Inst. Ch. E.*, 1961, **39** (3), 175-80.

Flow Patterns in Gas-fluidized Beds

Experiments were made to determine the direction and velocity of gas streams moving through fluidized beds by (a) injecting a visible trace of NO_2 and (b) measuring pressures around an artificial gas bubble.

It was found that gas inside a bubble moves up faster than the bubble. Gas that becomes directed into a bubble is not isolated, but rapidly returns to the solids through the roof and walls of the bubble. In the region of a bubble there is increased gas flow and solid movement, at the expense of remote regions where gas flow is reduced and solids are immobile. 5 refs.

P. F. Wace and S. J. Burnett, *Trans. Inst. Ch. E.*, 1961, **39** (3), 168-74.

Aggregative and Particulate Fluidization

A theory is offered to explain aggregative (bubbling) and particulate (smooth) fluidization. It is shown that large bubbles can be stable in most gas-fluidized systems, whereas in most liquid-fluidized systems the largest size of stable bubble is about the size of the solid particles. This explains why most gas-fluidized systems exhibit aggregative behaviour, and why most liquid-fluidized systems exhibit particulate behaviour.

The experimental evidence for the theory is examined, and it is shown that a transition from aggregative to particulate fluidization can be observed in both gas-fluidized and liquid-fluidized systems. 28 refs.

D. Harrison *et al.*, *Trans. Inst. Ch. E.*, 1961, **39** (3), 202-11.

Determining End of Laminar Region

In non-Newtonian fluids turbulent flow is achieved at different Reynolds numbers for different pipe sizes. This article shows how to determine where the turbulent region begins in such cases. Charts are included for 23 per cent lime slurry and 54.3 per cent cement-rock suspensions.

R. Le Baron Bowen, *Chem. Eng.*, 1961, **68** (13), 127-30.

Brit. Chem. Eng. Abstracts: **FOLIO No. 27**

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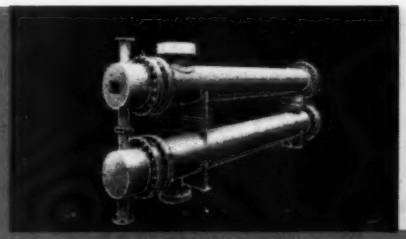

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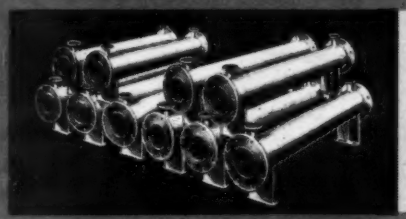

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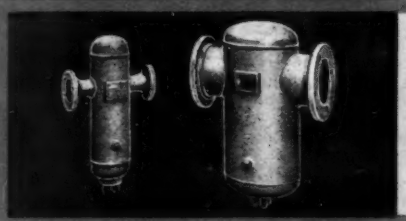

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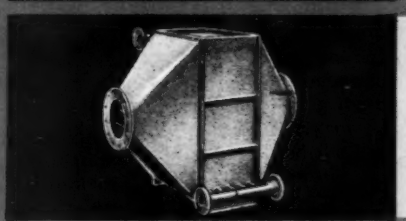
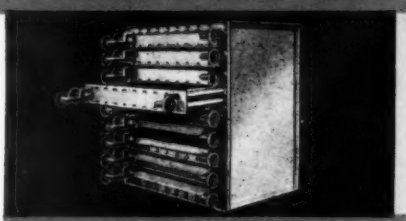


PROCESS AIR HEATERS



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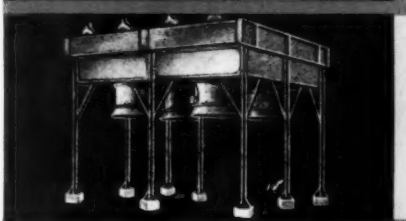

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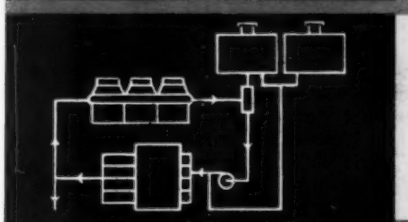

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Abstracts

GROUP B—HEAT TRANSFER

Flame Radiation in an Air-cooled Steel Muffle Combustor and a Complementary Water-cooled Furnace

These experiments were carried out with a short intense flame produced by a new air-cooled combustor. Heat flow to the flame tube wall as well as to the furnace walls has been studied. Compared with a long flame, for similar heat supply and excess air, the temperature of the exit flue gases is about the same with the short flame. Radiation to the muffle walls corresponds to the predicted value. However, the measured radiation to the portion immediately following the flame is higher than predicted.

N. E. Gunners and A. Lysholm. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part I, pp. 142-50.

The Effect of Flow Pulsations on Heat Transfer by Forced Convection from a Flat Plate

In these experiments the heat-transfer characteristics of the plate with steady air flow were the basis for comparison with pulsating flow tests. Heat-transfer observations with pulsating flow could be correlated by using the dimensionless parameter: half pressure amplitude/dynamic head corresponding to average rate of flow. No effect upon the heat transfer was found until this parameter reached a value of about 12. The heat transfer then increased as the 0.23 power of the pressure amplitude when the frequency was constant.

F. J. Bayley, P. A. Edwards and P. P. Singh. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part II, pp. 499-508.

Heat Transfer in Beds of Fluidized Particles—A Literature Survey

A review is given of the literature of heat transfer in fluid beds with particular emphasis on gas-supported systems, since these are of greater industrial importance at present. Some mention is, however, made of liquid fluidization. The period covered is approximately 1940-59. 55 pp.

H. Bannister. U.K.A.E.A. Research Group, Harwell. Report No. AERE-R.2996. Available from H.M.S.O., 9s. net.

Heat Transfer during Evaporation of High-quality Water-Steam Mixtures Flowing in Horizontal Tubes

The evaporation of steam was studied in a horizontal hair-pin type tube, 1.6-in. bore, for a variety of flow rates, steam pressure and steam quality, but at relatively low heat fluxes. Internal heat-transfer coefficients were measured during the transition from high "boiling" values to low superheated values.

Under all test conditions the coefficient dropped rapidly at steam qualities between 94-98 per cent, and the actual transition did not occur uniformly around the tube section. The coefficient dropped first at the top of the tube-section and then gradually spread around the sides to the bottom.

C. Rounthwaite and M. Clouston. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York 18, in *International Developments in Heat Transfer*, Part I, pp. 200-10.

An Experimental Investigation of Overall Heat-transfer Coefficients for Condensing and Boiling Hydrogen Films

These experiments were carried out at temperature gradients from 0.38° to 6.06°F with a single, smooth, vertical brass tube. Temperature difference between the condensing and boiling films was regulated and observed by changes in vapour pressure. Results were plotted as a function of temperature difference and of heat flux. They were compared with values reported in the literature and with values calculated from conventional design equations. Calculated values were sometimes off by a factor of 2 or 3. Further investigations are being conducted.

K. D. Timmerhaus, D. E. Dryer and J. W. Dean. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part II, pp. 270-6.

The Fusion of Granular Solids

The author reviews the methods available for calculating the molten film coefficients of heat transfer in mix melting and contact melting. A formula is proposed for calculating the limiting value of the overall heat-transfer coefficient.

T. K. Ross. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part V, pp. 919-25.

Heat Transfer Between a Flat Plate and a Pulsating Impinging Jet

Using air as the heat-transfer fluid, many experiments were made to determine the effect of jet velocity, jet frequency, wave form, impingement angle, nozzle to plate distance and test plate temperature, on the coefficient of heat transfer.

Heat transfer was independent of the pulsation frequency and amplitude. The relationship of Nusselt number, Nu, angle of impingement from horizontal, Φ nozzle to plate distance, L, nozzle diameter, d, and Reynolds number, Re, is given by:

$$\mathrm{Nu} = [7.1-0.095\,(L/d)]\;\theta^{[0.35-0.008(L/d)]}\left[\frac{\mathrm{Re}}{1000}\right]^{0.63}$$

for sine wave pulsations and steady flow, and by:

$$\mathrm{Nu} = [7.1-0.095\,(L/d)]\;\theta^{[0.35-0.008(L/d)]}\left[\frac{\mathrm{Re}}{1000}\right]^{0.60}$$

for square wave pulsations, $\theta = \Phi/90$, reduced nozzle angle, dimensionless.

R. G. Nevins and H. D. Ball. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part II, pp. 510-15.

Tests on a Rotating Tube Heat Exchanger having Controlled Fluid Flow

The principle of these tests consisted of increasing the surface heat-transfer coefficient by moving the solid surface concerned and restraining the fluid from following the motion freely. The apparatus consisted of two concentric annuli separated by a smooth tube, which could be rotated about its axis. Hot water passed along inner annulus and cold water along outer annulus in contra-flow. Overall coefficients were determined for a range of speeds.

Very high overall coefficients were achieved, some >6000 CHU/hr/sq ft/°C. Overall coefficients were sensitive to the flow direction in the inner annulus but not the outer annulus; and vanes had an effect when used in the inner annulus, not in the outer annulus. Thus the overall coefficient was in all cases (except zero speeds) determined by the inner surface coefficient.

R. F. Pattenden and A. D. Richards. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part V, pp. 903-11.

Heat Transfer by a Fluidized Bed

The author develops an approximate theory to explain the high coefficients obtained in fluidized beds and some of the unexplained and anomalous data reported on the subject. He submits the theory that high coefficients are explained by a "many times lesser thickness of a fluid interlayer between a wall and the first row of particles", and not so much by the thickness of a laminar layer or sub-layer. Moreover, the particles in this "row" are nearly as cool as in the bulk of the fluidized bed, in contrast to the heat transfer of a wall with a fixed bed, since the residence time of particles at a wall is very short. Experimental data of a number of investigators appear to confirm the theory.

S. S. Zabrodsky. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part IV, pp. 737-41.

International Developments in Heat Transfer—Part III

Many of the 17 papers published in this volume deal with heat-transfer studies in annuli, rod clusters, ducts, etc., at a variety of operating conditions, and are mainly of interest to designers of nuclear reactors. All the papers were presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18.

Relationship Between Pellet Size and Performance of Catalysts

This paper presents an approximate treatment of the simultaneous effects of heat and mass transfer. Three examples illustrate the results. The principal effects are associated with the variation of concentration within the pellet, and with the difference in temperature between the pellet surface and the bulk fluid. 13 refs

J. Beck, *A.I.Ch.E.J.*, 1961, **7** (2), 337-42.

Simultaneous Transfer of Heat and Mass—Part II

This paper deals with simultaneous heat and mass transfer in processes for air dehumidification or for water cooling with air.

J. Coates and B. S. Pressburg, *Chem. Eng.*, 1961, **68** (13), 131-4.

Brit. Chem. Eng. Abstracts: **FOLIO No. 28**

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AP65

Abstracts

GROUP C—MASS TRANSFER

A Lab-scale High-efficiency Vacuum Fractionation Unit

The unit described here has been constructed to purify the various intermediates and final products produced in the synthesis of high molecular weight naphthenic hydrocarbons. Packing used was a modified Stedman packing. The column performance was evaluated at 50 and 10 mm Hg abs pressure, using the test mixture of *o*-dichlorobenzene and *p*-diethylbenzene. H.E.T.P. of 1.85 and 3.27 cm were obtained at 50 and 10 mm Hg respectively.

A. A. MOHAJER, *J. Inst. Pet.*, 1961, **47** (450), 212-18.

Gas Absorption with First-order Chemical Reaction in a Spherical Liquid Film

Absorption rates of CO_2 and 1,1-dimethoxyethane vapour into spherical liquid films, in which they undergo first-order chemical reaction, have been measured. The diffusion equation, assuming an irreversible first-order reaction, has been solved. This enabled values of $c^*\sqrt{D}$ and k to be calculated from the experimental absorption rates. (c^* = equil gas conc in liq at interface; D = diffusivity of gas in liq; k = reaction velocity constant.) Good agreement was obtained with independent kinetic measurements of the velocity constant. This method may be used for the measurement of the kinetics of fast reactions. 12 refs.

G. A. RATCLIFF and J. G. HOLDCROFT, *Chem. Eng. Sci.*, 1961, **XV** (1/2), 100-9.

Mass Transfer in a Fluidized Bed

Mass-transfer coefficients have been measured in a small fluidized bed, in which vapours have been adsorbed from the fluidizing gas on to the surface of porous particles. An unsteady-state system has been employed. The coefficient is a maximum at the commencement of the process, and it progressively diminishes as resistance to transfer increases within the pores of the solid. The effects of back mixing are most significant at low Reynolds numbers. 21 refs.

J. F. RICHARDSON and J. SZEKELY, *Trans. Inst. Ch. E.*, 1961, **39** (3), 212-22.

Some Aspects of Adsorption

The first part of this article consists of a review of industrial separations, with reference to adsorbents and their applications to fixed-bed adsorption and fluidized-bed adsorption.

The second part deals with diffusion in adsorption and determination of diffusion coefficients, with reference to adsorption of benzene by activated charcoal. A classification of some molecular sieves is tabulated. 58 refs.

J. W. CARTER, *Birm. Univ. Ch. Engr.*, 1961, **12** (2), 42-56.

Rotation Columns and Other Types of Construction for Rectification at Pressures of 20 to 1 Torr

Plant scale rectification at low absolute pressures has led to the development of special equipment, since in conventional apparatus the pressure loss is too great or the efficiency too small. In this paper the author describes the operation and construction of the rotation column of the Kirschbaum-Stora system which on full load has a pressure loss of less than 0.1 torr per tray. (1 torr = 1 mm Hg abs press.)

F. NEUMANN, *Chemie Ing. Tech.*, 1961, **33** (7), 485-91.

Liquid-Liquid Extraction from Drops Accompanied by Chemical Reaction

Mass transfer accompanied by rapid chemical reaction was studied to elucidate the liquid-liquid extraction of acetic and butyric acids from solvent drops. The acids were transferred to aqueous KOH solution. Conclusions are the following:

(a) The transfer rates of acetic acid from benzene drops do not increase with addition of KOH to the aqueous phase; they decrease at a certain value of q (q = concentration of KOH in bulk of aqueous solution).

(b) Wherever this decrease occurs q/C_B is found to be constant (C_B = bulk concentration of solute in benzene).

(c) The transfer rates of butyric acid from benzene drops increase with increased q, but above a certain value of q the extraction rate decreases, when q/C_B is found to be constant.

(d) Other solvents, such as hexane, methyl-isobutyl-ketone, iso-propyl ether and butyl acetate, are classified in the two categories represented by acetic and butyric acids.

K. FUHNAWA and Y. NAKAIKE, *Chem. Eng., Japan*, 1961, **25** (4), 274-80.

GROUP E—PROCESSING

Reactions in a Fluidized Coke Bed with Self-resistive Heating

If an electric current is passed through a fluidized bed of conductive coke the temperature of the bed may be appreciably raised. With an appropriate gas the device becomes a chemical reactor.

This paper describes the design and operating characteristics of lab electrofluid units, which are usually Vycor tubes fitted with rubber stoppers through which electrical and gas connections are made. Temperatures of 1500°C are achieved in such units. Reactions studied include CS_2 from petroleum coke and H_2S; CS_2 from petroleum coke and S; HCN from NH_3 and hydrocarbons; HCN from NH_3 and coke. Some of these reactions show commercial promise.

H. S. JOHNSON, *Can. J. Ch. E.*, 1961, **39** (3), 145-7.

Benzene from Toluene by Detol Process

The Detol process, developed by Houdry Process Corp., produces almost theoretical yields of benzene from toluene and xylenes by catalytic hydrodealkylation. Toluene and hydrogen are reacted at 1000-1200°F and 500-1500 psig to produce benzene and methane.

ANON., *Pet. Ref.*, 1961, **40** (6), 228.

Problems of Industrial Sewage Disposal

This issue of the quoted journal deals exclusively with the problems of industrial sewage disposal. Several authors contributed in reviewing particular fields of the chemical industry where the problems of sewage disposal arise. These articles describe the waste water purification and disposal in the (a) synthetic rubber and synthetic alcohol industry (26 refs.); (b) production of viscous fibre (24 refs.); (c) cellulose and paper industry (11 refs.); (d) thermal processing of fuels (44 refs.); (e) oil refineries (9 refs.); (f) synthetic perfume industry (4 refs.); (g) industry of synthetic fatty acids; (h) acid and superphosphate producing plants. A separate article deals with the automation of waste water purification processes, and with the control of water quality (29 refs.): The importance of the satisfactory treatment of sewage water from the radiochemical laboratories becomes more obvious every day with the increasing use of isotopes in all branches of research. The Soviet standard of the maximum permissible radioactive isotope concentration of the different elements in the sewage water is given (12 refs.). The leading article discusses the possibilities of the regeneration of waste water for repeated use by thermal, physico-chemical or biochemical methods (75 refs.).

Zhur. Vec. Khim. Obsh., 1961, **2**, 122-214.

How Humble Oil Cut Pollutants by 80 per cent in Eight Years

This article shows how reductions in pollutants were affected, during 1952-1960, in the following sectors: (a) Pollutants due to combustion operations reduced by using fuel of lower S content, by not burning H_2S and acid sludge, by installation of smokeless flues, and by reduction of emergency flaring. (b) Pollutants due to evaporation and leakage losses reduced by installing floating roof tanks, by using vacuum trucks to pick up spilled oil, and closed pre-separators for skimming oil from sewer water. (c) Pollutants from catalyst dusts reduced by increasing capacity of recovery equipment, by using stronger catalysts, and by eliminating waste-heat boiler cleanings.

D. H. STORMONT, *Oil Gas J.*, 1961, **59** (6), 124-8.

Oxidation Processes in the Petrochemical Industry. Part I: Vapour Phase Processes

The article contains a list of the principal chemicals produced by oxidation processes and the feedstocks used. Vapour phase oxidation processes are classified according to the catalytic methods used: thermal, heterogeneous and homogeneous. Many processes are briefly outlined.

P. W. SHERWOOD, *Pet. Eng.*, 1961, **33** (2), C10.

New Synthesis Method for a Gasoline Antioxidant

A two-step process is described for the synthesis of 6-tert-butyl 2,4-xylenol, a potent gasoline antioxidant, by methylation of 6-tert-butyl-o-cresol. In this process, addition of a methyl group only requires the consumption of formaldehyde and hydrogen.

E. P. PREVIC *et al.*, *Ind. Eng. Chem.*, 1961, **53** (6), 469-70.

Glass Wool in Industrial Insulation

This paper describes French glass wool manufacture, essentially a synthesis of former German and American techniques, and the range of insulating products available.

J. TOURNEUR, *Génie Chim.*, 1961, **85** (5), 209-16.

Brit. Chem. Eng. Abstracts: **FOLIO No. 29**

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Abstracts

GROUP H—DESIGN

Application of the Rotating-disc-type Extraction Column in the Coal Processing Industry

The rotating-disc-type extraction column was used successfully for the removal of phenols from waters formed during the low- or high-temperature distillation or gasification of coal. The phenols were extracted from the water phase into the neutral-oil phase. By neutral oil a neutralized light fraction of the coal tar distillation was meant, which moved upwards in the column and constituted the dispersed phase. If free NH_3 was present, this greatly reduced the efficiency of extraction. However, NH_3 in even a loosely bound form, such as $(NH_4)_2CO_3$, did not cause any significant effect. It has been concluded that for the given column 618 rpm, 7-7.2 m^3/m^2 hr loading, 3-3.2 ratio of the continuous to the dispersed phase were the most efficient operating conditions. Under these circumstances the efficiency of extraction was over 90 per cent. The efficiency was found to be directly proportional to the speed of rotation, but with increase in speed the loading had to be decreased. The H.E.T.S. of the rotating-disc-type extractor was only about one-third of the H.E.T.S. value of a similar spray extraction column. 7 refs.

L. Harmathy and B. Raskai, *Magy. Kém. Lapja.*, 1961, **4**, 173-7.

Hydraulic Problems of the Chemical Reactors Handling Gas-liquid Systems

The authors have attempted to find answers to several only yet partially solved problems. The following were experimentally proved: (1) the height of the liquid layer above the perforated plate and the presence of neighbouring perforations do not affect the frequency of bubble formation; (2) some of the gas bubbles unite into bigger aggregates and these pass upwards in the liquid layer much faster than the also-present small single bubbles; (3) increase of the surface tension of the liquid is associated with slower bubble formation, which is particularly apparent at smaller gas rates; (4) the viscosity of the liquid has only small effect on the gas content of the liquid layer. Two equations are given for calculating the gas content in the liquid layer and the mean velocity of the gas through the liquid layer. These equations are applicable for liquids and gases of different physical properties in wide range of temperature, pressure and physical dimensions of the system. 14 refs.

M. B. Aisenbud and V. V. Dilman, *Khim. Prom.*, 1961, **3**, 51-6.

Control of $CaSO_4$ Concentration in Sea-water Evaporator Seeded with Anhydrous $CaSO_4$ Crystal

A theoretical treatment has been developed to determine the concentration of $CaSO_4$ in sea-water evaporators, seeded with anhydrous $CaSO_4$ crystals to control the formation of hard scale of $CaSO_4$. Equations and charts are provided to determine both steady-state and transient behaviour of the degree of supersaturation of the scaling material in the evaporating liquor.

Published data on concentrated-sea-water evaporators, seeded with anhydrous $CaSO_4$ crystals, are analysed by this correlation, and good agreement is found between the calculated and measured concentration values. Recommendations are made which relate to the design of such evaporators.

T. Miyauchi and T. Moriyama, *Chem. Eng., Japan*, 1961, **25** (6), 460-8.

Tentative Designs for Two Geometrically Ever-safe Mixer-settlers for High Volumetric Throughputs

High-throughput, geometrically-safe solvent extraction equipment will be required to efficiently process the large quantities of spent fuel expected from future commercial nuclear reactors. One promising design is an array of mixer-settlers in an ever-safe slab. However, a pumping impeller, or a similar device, is required to produce the driving force in a horizontal slab.

The first design described has the stages on top of each other. This eliminates the need of an impeller, but introduces difficulties of construction and stability. The second is a horizontal design with a marine impeller, which maintains a large difference in level between the mixer and settling compartments. Liquors flow from the settling compartments over weirs which eliminate back mixing. The unit is simple, flexible and provides ideal settling conditions. Small models of both designs have been operated successfully and the second is recommended for development.

C. Hanson and M. J. S. Smith, U.K.A.E.A. Report No. TRG, Report 22(R). Obtainable from H.M.S.O., 3s. net.

Performance Coefficients for Cooler Condensers in the Gas Industry

The results of tests on four gasworks coolers-condensers of widely differing construction have been analysed, and the coefficients are in good agreement with those predicted by a method which uses the Stevens' chart, proposed by Carey and Williamson. Mass transfer coefficients do not vary throughout the condenser, as predicted by theory, and this is attributed to additional resistances at the hot end of such condensers.

G. S. Cribb. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part V, pp. 912-18.

An Analysis of Heat Transfer in the Hickman Rotary Evaporator

This paper describes a method for analytically determining the overall heat transfer coefficients of a Hickman rotary evaporator, which could serve as a prototype for large commercial units. Overall condensation/evaporation heat transfer coefficients ranged from 3200-4400 Btu/hr/sq ft/°F, using fresh-water feed. The theoretical expression derived indicates that, within the range of variables studied, the heat-transfer coefficient is independent of rotor diameter, and varies with rotational speed at a rate proportional to $^2\sqrt{\text{RPM}}$.

Experimental performance of a lab unit was 10-15 per cent below the predicted coefficient. This deviation is very small.

A. A. Putnam *et al.* Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part V, pp. 886-94.

Heat Transfer and Pressure-drop Data on Cooling Tower Packings

The paper presents heat-transfer and pressure-drop data obtained in a 4-ft-square experimental cooling tower for 18 splash packings and 23 arrangements of asbestos-cement sheets, both flat and corrugated; it also gives data on fine, free-falling spray.

The resistance to air flow through an empty tower is treated theoretically and shown to depend on the ratio of shell diameter to height of the air inlet opening. This is extended to the case of packed towers by model experiments, and a simple empirical expression is derived for the total resistance to air flow through the towers.

H. J. Lowe and D. G. Christie. Paper presented at the 1961 International Heat Transfer Conference, held at the University of Colorado, U.S.A. Published by A.S.M.E., 29 West 39th Street, New York, 18, in *International Developments in Heat Transfer*, Part V, pp. 933-50.

Utilisation of Waste Heat Gases for Site Heating at the National Gas Turbine Establishment, Pyestock, Farnborough, Hants.

The article records the salient features of an installation considered to be unique. This was a project laid down by the Government to obtain data on gas turbine work in the industrial field, and the first to utilize waste heat gases for site heating.

For clarity, the article has been divided into three sections, and they each have a bearing on one another.

Section I: The 10-MW Gas Turbine Power Station, with explanations of the turbine plant, including waste heat exchangers and pass-out turbine.

Section II: The Main Boiler Plant for the 14,000-hp Turbine Test House (Battle House).

Section III: Site Heating, with explanations of the steam/water heat exchanger plant.

P. M. Warrell, *Inst. Heat and Vent. Eng.*, 1961, **29**, 1-15.

A Design Parameter for Multicomponent Tray Design Estimates

This report develops computational techniques that are useful in multicomponent distillation. A design parameter, $(\partial n/\partial N)_s$, is introduced, which is equal to the number of theoretical plates equivalent to one total reflux tray at the bottom of the enriching section. For a minimum sized tower $(\partial n/\partial N)_s$ is less than 3.5. Economic conditions permit values as high as 6.

A procedure is included for evaluating the reflux leaving the enriching section, L_s, after a value for the design parameter has been selected.

A. J. Surowiec, *Can. J. Ch. E.*, 1961, **39** (3), 130-8.

Precision Distillation Columns

This paper describes a precision distillation column for separating mixtures of closely boiling components. The column consists of parallel tubes which can be packed or unpacked, and in which operating conditions can be exactly maintained. The operation of the apparatus and results obtained are also discussed.

W. Kuhn, *Chemie Eng. Tech.*, 1957, **29** (1), 6-19. Translated by R. Todd. U.K.A.E.A. Research Group, Harwell. Report No. AERE-Trans. 850, 22 pp.

Brit. Chem. Eng. Abstracts: **FOLIO No. 30**

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Abstracts

GROUP G—MISCELLANEOUS

Centrifugation Equipment—A Review
Part I: Theory

Centrifugation theory is reviewed with reference to the gas centrifuge, the ultra centrifuge, the industrial centrifuge, liquid-liquid separation centrifuges and centrifugal filters.

C. M. AMBLER, *Ind. Eng. Chem.*, 1961, **53** (6), 430-3.

Part II: Design

The design of centrifuges is considered with reference to clarifying efficiency, bowl stresses, bowl stability, corrosion, and power requirements.

F. E. SULLIVAN and R. A. ERIKSON, *Ind. Eng. Chem.*, 1961, **53** (6), 434-8.

Part III: Applications

Numerous machines are described and illustrated, together with their applications: sedimentation centrifuges, filtering centrifugals of various types.

J. C. SMITH, *Ind. Eng. Chem.*, 1961, **53** (6), 439-44.

Centrifugation—Unit Operations Review

Several new centrifuges, developed by major centrifugal equipment manufacturers, and their applications are reviewed.

J. E. FLOOD, *Ind. Eng. Chem.*, 1961, **53** (6), 489-91.

Chemical Engineering Pilot Plants

This article discusses the function of the chemical engineering laboratories and pilot plants in training chemical engineers at the Institutes of Chemical and Physical Technology at Delft Technical University. Very good results are achieved by combining plant units ranging from small-scale to semi-technical production scale which familiarize the student with actual chemical processes.

P. M. HEERTJES, H. KRAMERS and J. C. VLUGTER, *Chem. Proc. Eng.*, 1961, **42** (7), 297-302.

Bulk Handling of Liquid SO_3

This paper describes the properties of the allotropic modifications of SO_3, and discusses them in relation to the properties of the stabilized liquid "Sulfan". Details related to design and precautions, based on experience, are also included.

B. O. DAVIES, *Chem. Engr. (Lond.)*, 1961 (155), A47-A51.

Bulk Supply of Hydrogen

By-product hydrogen from electrolytic processes is now profitably sold due to the development of suitable road transport vehicles. This paper describes the vehicle approved by the Home Office.

G. J. LEWIS, *Chem. Engr. (London)*, 1961, (155), A56-A58.

Closed-circuit Grinding

The author describes how throughput was increased and bottlenecks eliminated at an installation for grinding degreased fat residues. He presents ideas which should increase production, reduce labour and power costs of closed-circuit grinding systems.

C. A. LEE, *Chem. Eng.*, 1961, **68** (11), 112-13.

Pyrex Glass Pipes

This paper describes how Pyrex pipes are assembled, with reference to the various parts: caps, asbestos and rubber packings, cast-iron flanges, Teflon joints and bellows. Pyrex cocks equipped with a Teflon valve are highly resistant to thermal and pressure shocks and to corroding agents.

F. SAMOUR, *Génie Chim.*, 1961, **85** (5), 188-99.

Industrial Glass Heat Exchangers

The author compares karbate and glass heat exchangers, and describes various types of available Pyrex heat exchangers; i.e., coil, tube, liquid film, double-walled.

J. VEILLON, *Génie Chim.*, 1961, **85** (5), 183-7.

Galvanic Corrosion of Glass Tank Refractories

In this paper the rate of corrosion reaction has been determined from the current generated by an electrolytic cell. Corrosion of refractories by molten glass is accelerated by the electrical potentials which are established if combinations of certain refractories are exposed to the molten glass. The extent of this corrosion can be predicted from the half cell potentials between the refractory and the molten glass as electrolyte. Corrosion of the more positive refractory is increased when used with a less positive refractory, whereas the latter receives some protection.

F. J. SHONEBARGER, *Glass Tech.*, 1961, **2** (2), 53-9.

Errata

The references to the three abstracts on Folio 21, p. 494, July issue, by the authors A. DEVORE, T. D. MCMINN, JR., and R. H. MEIJER respectively, should have *C.E.P.* replaced by *Pet. Ref.*

Similarly for the abstract on Folio 25, p. 564, August issue, by authors W. M. THOMAS and W. C. MALLISON.

Investigation of the Automatic Adaptation of Gas Burners to Different Gases

Grid gas, natural gas and liquefied petroleum gas may all be burned effectively in the same burner if the nozzle, the primary air inlets and the combustion area are adjusted accordingly. These adjustments are carried out automatically using the density of the gas as the control factor. The apparatus is expensive and would only be economic on a large scale.

F. SCHUSTER, *Gas-u. Wasserfach*, 1960, **101**, 1162-5.

Possibilities of Using Nuclear Energy for Gasifying Coal

The proposed system is the indirect process cycle with helium heated in a nuclear reactor, and passed through an exchanger-type gasifier for the reaction of coal and steam to form CO and H_2.

J. P. MCGEE and S. KATELL, *Inform. Circ. U.S. Bur. Min.*, 1960, 7963.

Determination of the Particle Size Distribution Curves of Powders

Based on the earlier established kinetic equations of sedimentation, a new analytical method has been put forward to solve the equations of differential and integral curves of the particle size distribution. The experimental results and the deduced formulæ have proved that powders are not mixtures of random size particles; their characteristics follow mathematical expressions. The dispersity of particles can be described by two experimentally-found constants. A table is given from which the differential curves of distribution can easily be drawn without complicated calculations, if the values of the two experimental constants are known. Using the same constants, the minimum, the most probable and the maximum particle size can also be found. Comparison of the analytical method with the graphical method has revealed the serious inadequacies of the later one. The presented analytical method has wide applications for both sedimentation and sieving operations, and has proved to be useful in biochemical research for the determination of the relative distribution of high molecular weight compounds. 6 refs.

N. N. TSIURUPA, *Khim. Prom.*, 1961, **3**, 37-42.

Quick Determination of the Investment Costs of Chemical Plants and the Analysis of the Effectiveness of Investments

After a brief survey of the Western methods of investment cost calculations, the author carries on showing how the investment costs for a new chemical plant installation are arrived at in Hungary at the present. In capitalism the profit return is the unique and totally satisfactory index for the determination of the effectiveness of an investment. Under socialist production conditions profit as an economical concept does not exist, and the effectiveness of an investment must be evaluated on a different basis. It was decided in 1956 that in order to get a realistic and correct picture of an investment problem, calculations should be carried out both at company and at national levels. Two formulæ have been established which, after some modifications in their present forms, are:

Effectiveness of investment

(1) At company level $Gu = \dfrac{T - Ai - Ab - L}{M + Eh}$

(2) At national level $Gn = \dfrac{T}{M + Ab + Ai + L + Eh}$

where T = value of one year's total production;
Ai = imported raw materials, semi-finished products and energy costs;
Ab = material costs (other than imported);
L = depreciation;
M = total labour costs;
Eh = factor, expressing loss of national income due to tying down of national capital. Numerically 0.2 times the value of the tied-down capital.

These indices are worked out to two decimal places and then compared with the data of different production technologies for the same product, or with other products before a decision concerning the investment is made. Examples are given for production cost and pay-out time calculations. The article might be worth studying in detail for anyone engaged in commercial activities with the socialist countries. 8 refs.

P. REVESZ, *Magy. Kém. Lapja.*, 1961, **4**, 165-72.

Brit. Chem. Eng. Abstracts: **FOLIO No. 31**

. . . in the Organic and Fine Chemicals Laboratory. There are lots of other girls in all sorts of jobs and I must say they all seem very happy at Berk. But I'm told it's always been the same here, ever since we started ninety years ago. I'm a control lab. analyst, testing chemicals used in anything from cosmetics to cleaning agents and in industries as different as agriculture and road building. Part of my own duties is to determine the purity of potassium bromate used in such contrasting end-products as a neutraliser for "cold perms" and an anti-shrink agent for the woollen trade. And I know our chemicals are used in lots of other things—food and rubber and plastics and soaps and textiles and leather and greases and fuel oils and goodness knows what else. There must be scores of applications of which I've never even heard. As one of our chemists says—"When it comes to serving industry, Berk serves nearly everyone."

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EMERGENCY VENT SIZE FOR TANKS CONTAINING FLAMMABLE LIQUIDS

by D. S. DAVIS
University of Alabama

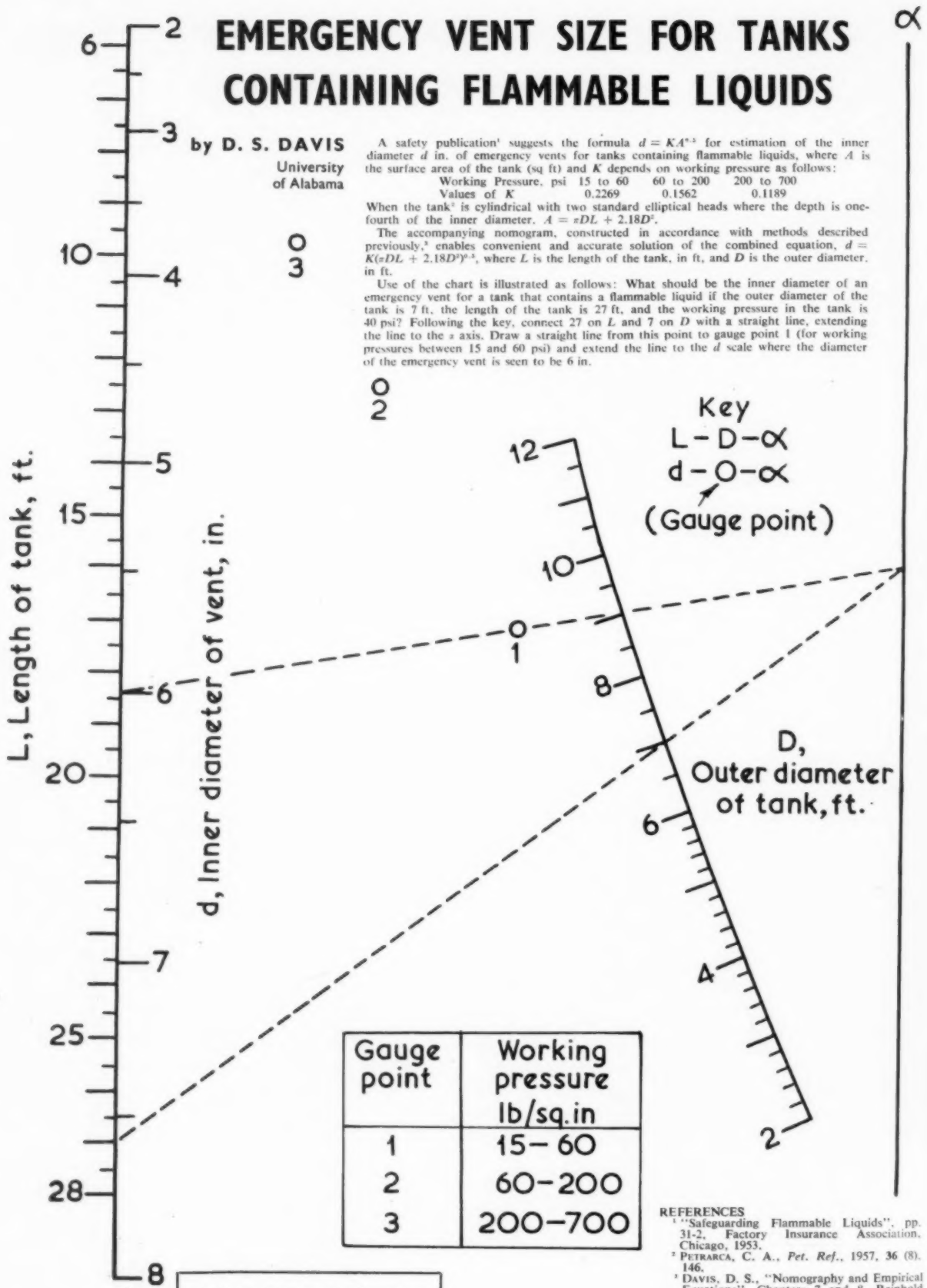
A safety publication[1] suggests the formula $d = KA^{0.5}$ for estimation of the inner diameter d in. of emergency vents for tanks containing flammable liquids, where A is the surface area of the tank (sq ft) and K depends on working pressure as follows:

Working Pressure, psi	15 to 60	60 to 200	200 to 700
Values of K	0.2269	0.1562	0.1189

When the tank[2] is cylindrical with two standard elliptical heads where the depth is one-fourth of the inner diameter, $A = \pi DL + 2.18D^2$.

The accompanying nomogram, constructed in accordance with methods described previously,[3] enables convenient and accurate solution of the combined equation, $d = K(\pi DL + 2.18D^2)^{0.5}$, where L is the length of the tank, in ft, and D is the outer diameter, in ft.

Use of the chart is illustrated as follows: What should be the inner diameter of an emergency vent for a tank that contains a flammable liquid if the outer diameter of the tank is 7 ft, the length of the tank is 27 ft, and the working pressure in the tank is 40 psi? Following the key, connect 27 on L and 7 on D with a straight line, extending the line to the α axis. Draw a straight line from this point to gauge point 1 (for working pressures between 15 and 60 psi) and extend the line to the d scale where the diameter of the emergency vent is seen to be 6 in.



Gauge point	Working pressure lb/sq.in
1	15–60
2	60–200
3	200–700

REFERENCES
[1] "Safeguarding Flammable Liquids", pp. 31-2, Factory Insurance Association, Chicago, 1953.
[2] PETRARCA, C. A., *Pet. Ref.*, 1957, 36 (8), 146.
[3] DAVIS, D. S., "Nomography and Empirical Equations", Chapters 7 and 8, Reinhold Publishing Corporation, New York, 1955.

British Chemical Engineering
NOMOGRAM NO. 62

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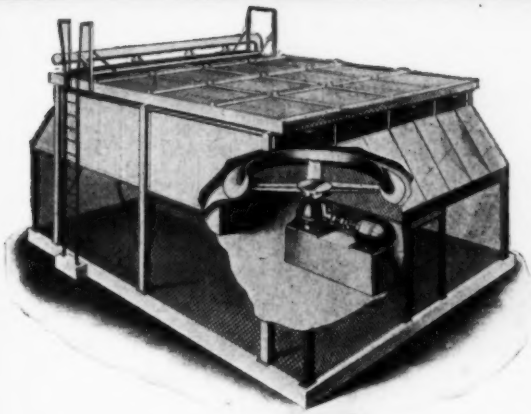
provide guaranteed temperature control and economic operation

The simple and robust construction of the fin-fan, which is made up of a minimum number of standardised parts, combines appearance with utility. These forced draught coolers are powered by electric motors, gas or diesel engines, steam turbines, etc., using adjustable pitch propeller type fans, and can be employed in a great variety of waste heat dissipation duties at pressures from vacuum to 5,000 p.s.i. or temperatures to 1,500°F.



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P.6456

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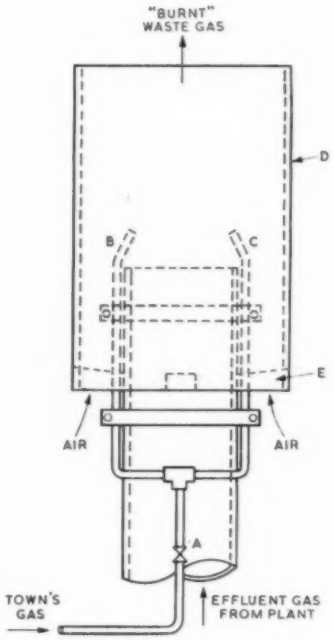
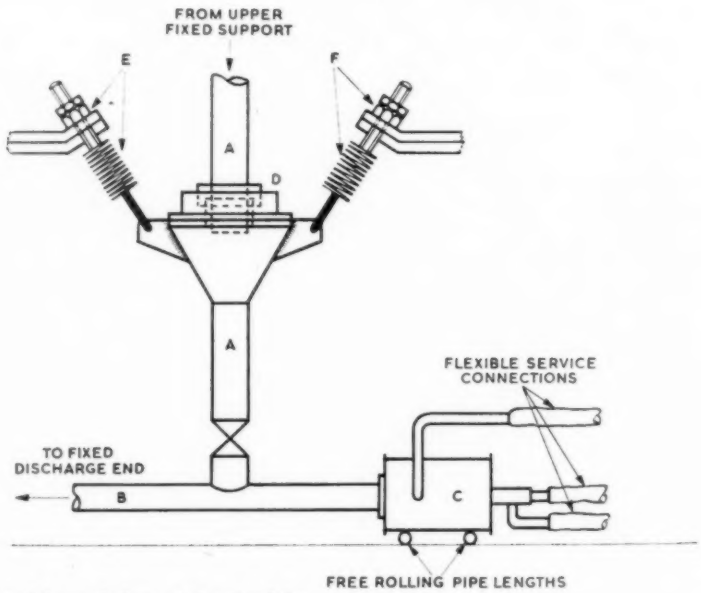
A Convenient Pilot Plant Flare Arrangement for Dirty Waste Gas



IN pilot scale development work one is often confronted with the problem of finding a convenient disposal method for effluent gases containing impurities which would prove objectional if merely released into the atmosphere. Often a washing or scrubbing train is used for this purpose, but in the case of contamination of basically inert effluent gas by small amounts of inflammable material such as soot or tarry vapours, a simpler method is to use some form of flare arrangement. The requirements of such an arrangement are that it should generate sufficient heat at the mouth of the effluent pipe to effect rapid combustion of the contaminants as they flow into the atmosphere and also be stable under blustery conditions.

The diagram shows a flare arrangement which meets the above requirements and has been used successfully over a long period on effluent gases contaminated by sooty and tarry material. Towns gas was supplied at two points just above the mouth of the effluent pipe through valve (A) and pipes (B) and (C) (strapped to the effluent pipe). This arrangement was surrounded by a pipe (D) of 1½ in. to 2 in. larger bore than the effluent pipe and was supported from the effluent pipe by a simple welded spider arrangement at (E). Gas was turned on at valve (A) and ignited above the mouth of the effluent pipe using a long rod with a flaring paraffin-soaked pad wired on the end. Air for combustion was drawn upwards through the annular space between the effluent and outer pipes; combusted waste products passed from the top. The length of outer pipe required and the flow rate of gas to be used are determined to suit the particular case.

Expansion Allowance Problem



THE diagram shows how a "two-way" expansion problem was overcome by using a combination of a previously described expansion joint (1), adjustable tension spring supports, a roller arrangement and flexible service connections. Solid at temperatures in the range 300-600°C passed down 3 in. diameter standpipe (A) into a long 2 in. diameter transport line (B) where it was picked up by hot flue gas generated in a pig (C) and its temperature raised to 800°C.

The expansion directions were as follows:

(a) Standpipe (A) vertically downwards from its topmost, fixed support.
(b) Transport line (B) horizontally to the right of the diagram from a fixed discharge end on the left.

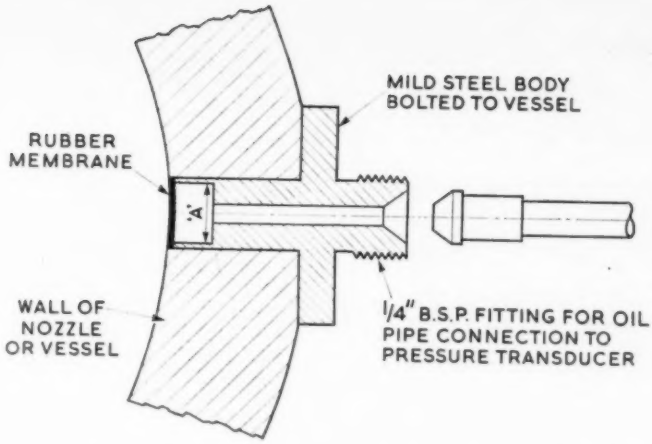
The expansion and support of the standpipe were allowed for by installing a simple expansion joint (1) at (D), and suspending the "floating" lower half of the standpipe from adjustable tension springs (at E and F). This combined arrangement gave free elongation to both upper and lower halves of the standpipe, and in addition, allowed lateral movement of the lower half to follow horizontal transport line expansion. The transport line and pig were supported on free rolling pipe lengths (as shown) with reinforced flexible service connections to the pig. Thus the transport line itself was free to expand in its natural direction.

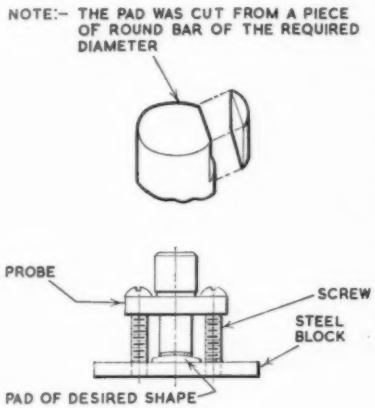
(1) *Brit Chem Eng.*, Proc. Eng. Notebook, May, 1959.

A Pressure Sensitive Probe

THIS probe was designed to measure the pressure within the nozzle of an extrusion press compacting fine powder. However, its use can be extended to any system where it is required to measure the pressure exerted by fine solids on a vessel wall, e.g. bottom of hoppers, and in fluidized and dispersed phase solid systems.

The pressure sensitive probe as used in nozzle pressure measurement is illustrated in the diagram and was made as follows:


MILD STEEL BODY BOLTED TO VESSEL
RUBBER MEMBRANE
'A'
WALL OF NOZZLE OR VESSEL
1/4" B.S.P. FITTING FOR OIL PIPE CONNECTION TO PRESSURE TRANSDUCER



The steel body was machined so that when the rubber membrane was secured in position it followed the contour of the inside of the nozzle. The membrane was made from nylon reinforced rubber about .050 inch thick and was secured in position with a suitable type of cement. The probe was connected to a pressure transducer with the shortest possible pipe length to minimize the effect of the compressibility of the oil, and the system was carefully filled with hydraulic oil taking care to exclude air through a suitable bleed point. It was for this reason that a pressure transducer was used and not a pressure gauge, as the latter would be very difficult to bleed completely.

Pressures inside the nozzle were determined by using the oil pressure reading in the probe as applied to the area of the chamber of diameter 'A'. The dimensions of the probe depend upon its applications, and many factors, such as particle size of the material, curvature of the vessel, and sensitivity of readings required, could influence modifications in design.

In this particular application, the probe proved successful where strain gauge probes were unsatisfactory.

A small jig was made for attaching the rubber membrane to the probe. This is shown in the second diagram and it causes an even pressure to be maintained on the contact surfaces while the adhesive is setting. The adhesive used was an "Araldite" epoxy resin, which was cured in an oven at 175°F for 3 hr.

JAMES COCKBURN

A Jet of Film Type Towers

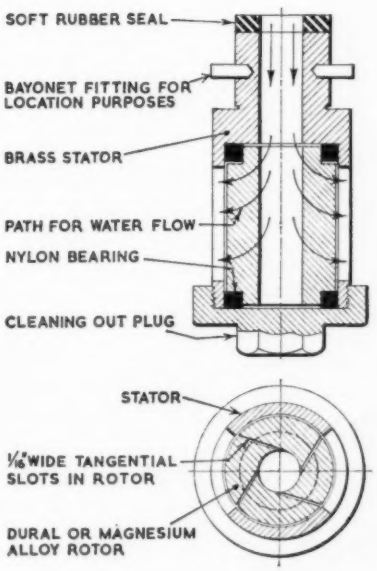
A JET as illustrated in the attached sketch was devised for the spreading of a liquid film on to adjacent sides of a tower packing.

The rotor is rotated by the pressure of the liquid in the manner of a centrifugal pump impeller inside its casing, the liquid being deflected on to the sheet packing by the stator shroud.

The attachment of the jet to the liquid supply is by means of a bayonet fitting which positively locates the stator shroud with the openings opposite to the sheet packing.

Although this jet was developed for pilot plant tower tests it is felt that it could be of considerable use in full scale mechanical draught cooling towers, where the ability to provide a continuous liquid film without entrainment and with no pressure loss on the gas side together with the use of the new Firth-Cleveland lawn-mower blade ultra high efficiency fan, might put the induced draught tower in a position of overwhelming superiority over the natural draught tower.

F. MOLYNEUX



Contributions Invited

The Editor invites contributions to "Process Engineer's Notebook". They should preferably deal with practical devices designed to overcome problems for which standardized equipment is not available; hints for the improved design of conventional equipment; methods of improving equipment operation; safety devices; etc. For the most meritorious contribution the sum of **10 gns.** will be paid, while other contributors will receive **5 gns.** They will be published anonymously or under the contributor's name, according to his wishes.

Book Reviews

Proceedings of an International Symposium on High Temperature Technology
Arranged by the Stanford Research Institute.
McGraw-Hill Book Co., New York, 1960, 348 pp., 116s. 6d.

NOT only rocket scientists but process engineers in the metallurgical and refractories industries are vitally interested in high temperature phenomena. Many aspects of this field were presented at a Symposium on high temperature technology arranged by the Stanford Research Institute in 1959. The full proceedings, including the discussion, were subsequently published by McGraw-Hill. These form an excellent contemporary review outlining the present frontiers of this new technology.

The conference discussed the chief aspects under the headings of techniques and measurements, materials and materials behaviour, and high temperature processes with reference largely to work in the United States. There were also review papers on work in England, France, Germany, Scandinavia and Japan by authors from these countries. Perhaps the two applied topics of greatest interest were high temperature materials, which were subdivided into sections on metals, non metals and intermetallics (e.g. silicides, borides, aluminides, graphites, carbides) and high temperature processes. The application of such materials as CeS, melting at about 2500°C with high electrical resistance and low thermal expansion has intriguing possibilities.

The chapter on the combination of high temperatures with high pressures was written by H. TRACY HALL, one of the co-workers on the original synthetic diamonds made by General Electric of Schenectady. Further chapters deal with fused salts and high temperature chemical syntheses, and pycometallurgy.

The papers are written as critical outlines of their particular fields rather than merely unselective lists of references and would serve well either to introduce the lay scientist to high temperature research or to widen the outlook of workers in specialized high temperature processes.

W. STRAUSS

Thermodynamic Functions of Gases: Vol. 3, Ethane, Methane, Nitrogen
Edited by F. Din
Butterworths, London, 1961, 63s.

THE three compilations of thermodynamic properties appearing in this volume originate from industrial laboratories but fall within the survey promoted by the D.S.I.R. Mechanical Engineering Laboratory.

The correlations for methane and ethane were prepared by H. E. TESTER of the British Petroleum Company and cover the ranges 100-470°K, 1-1000 atm and 180-500°K, 1-500 atm respectively. Both diagrams appear to have been completed before, and therefore without reference to, ROSSINI's 1957 compilations; but there seems to be satisfactory agreement between the two sources.

The nitrogen diagram is by F. DIN of the British Oxygen Company. It covers a far wider range (60-700°K, 1-10,000 atm) than any previous diagram and includes the solid phase. All users of thermodynamic diagrams would gain from reading the account of this compilation. It shows just how uncertain are the values of the thermodynamic functions for this reference substance in pressure and temperature regions frequently encountered.

Large wall charts of the T-S. diagrams of the three substances are available.

G.G.H.

The Structure of Electrolytic Solutions
Edited by Walter J. Hamer
John Wiley & Sons Ltd., New York and London, 1959, pp. xii + 441, 148s.

THE theory of electrolytic dissociation postulated by ARRHENIUS in 1887 marked the beginning of modern electrochemical theory. Studies of electrolytic solutions by ARRHENIUS, VAN'T HOFF and OSTWALD and their contemporaries, laid the foundation to a subject which was rapidly to assume enormous theoretical and practical importance.

The years following World War II have witnessed the accumulation of a vast quantity of information on electrolytic solutions, and "The Structure of Electrolytic Solution" covers current work in this field. A truly comprehensive treatment of the subject would obviously require a volume many times the size of the present one, but the wide range of subjects covered includes the most significant of those at present under investigation.

The book is based upon papers presented by experts on electrolytic solutions from various parts of the world at a symposium held in Washington, D.C., in 1957. Some of the chapters are essentially like the papers that were presented at the symposium, others are the result of further thought and deliberation. Topics extend from dilute solutions to the pure ionic solid state, including concentrated solutions and fused electrolytes. Use is made of thermodynamics and statistical mechanics in describing the state of ions in various media. Activity and Osmotic coefficients are considered from various viewpoints. Some recent concepts on ion solvation and ion transfer are presented, and new information on ion diffusion discussed. An appreciable part of the volume is devoted to the structure and properties of complex ions, ion pairs, polyelectrolytes, fused salts, ionic crystals and the rare earths. Several new experimental methods for investigating the equilibria and kinetics of electrolyte solutions are evaluated.

This book provides a very useful reference to recent advances in the field of electrolytic solutions, and as such would appeal more to the specialist. It should be of great value to the scientist or research student entering this particular field of study. The book is well produced, but the price is rather high.

J.F.H.

Modern Coordination Chemistry, Principles and Methods
Edited by J. Lewis and R. G. Wilkins
Interscience Publishers Inc., New York and London, 1960, 487 pp. 80s.

THE current and growing interest in coordination chemistry make the appearance of this first British book to be published in this field particularly welcome. Since the war there has been a tremendous upsurge in this branch of chemistry made possible by the application of modern physical methods.

The professed aim of the editors of the book is "to enable the researcher or potential worker in this field to assess the applicability of a particular method to his problem". This the contributors have achieved very successfully through a discussion of the theory and experimental techniques of coordination chemistry. There is a welcome emphasis on the quantitative aspects. The chapters cover authoritatively the thermodynamics of metal ion complex formation in solution; the reaction rates of transitional metal complexes; the isomerism, visible and ultra-violet spectra and magnetochemistry of complex compounds, the infra-red spectra of transitional metal complexes. The emphasis throughout the book is on the coordination compounds of the transition metals and on coordination reactions in aqueous media.

The book is generally very readable, exceptionally well referenced and very well produced.

M.P.

Progress in Cryogenics: Vol. III
Editor: K. Mendelssohn
Heywood & Co., London, 45s.

THE applications of low temperatures both on the large scale and in the laboratory are still proceeding apace. The further dissemination of knowledge of low temperature techniques and equipment contained in the third volume of this progress series will therefore be valued. It contains six articles, all of a high standard, but differing greatly in emphasis and complexity.

A. J. CROFT (Clarendon Laboratory, Oxford) provides a useful review and critical comparison of helium liquefiers, both laboratory-tailed and proprietary. MRS. A. G. LENFESTRY (Marston Excelsior Ltd., Wolverhampton) describes the use of secondary-surface heat exchangers for low-temperature duties, and includes a useful introduction to the design methods employed. W. E. GIFFORD gives more details of the new miniature low temperature cooling units developed by A. D. Little Co. (Massachusetts). The ingenuity both of functions and construction of these machines is of a high order and deserves study. The fourth paper presents a fascinating account of the use of low-boiling liquids in rocketry and is by I. E. SMITH (Rolls-Royce Ltd., Derby).

The remaining two papers deal with experimental aspects of low temperature nuclear orientation. R. P. HUDSON (N.B.S. Washington) discusses the choice of suitable paramagnetic substances and C. D. JEFFRIES (University of California) describes dynamic methods. Neither article is for the general reader.

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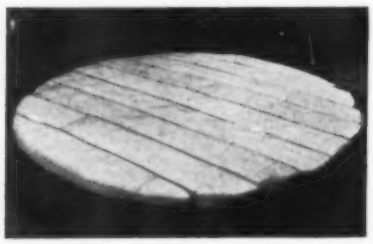
PLANT EQUIPMENT NEWS

Demister made from Propylene

Advantages of excellent corrosion-resistance, greater lightness than the metallic equivalent and lower cost compared with similar constructions in monel or stainless steel are among the main advantages of a new KnitMesh demister.

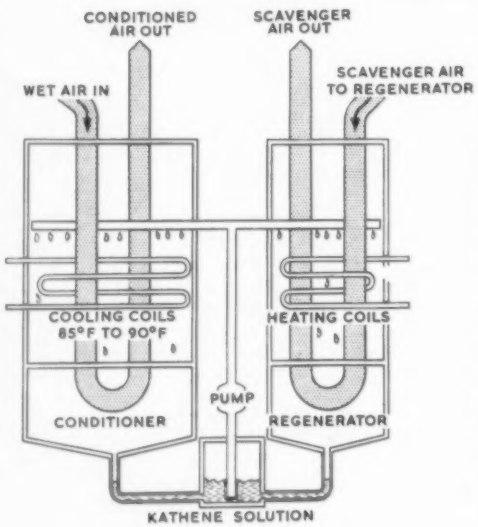


Demister slabs can be supplied in widths of 12 in. and in various lengths and shapes. As the photograph shows, it is quite easy to fit a series of such slabs into a 9-ft-dia vessel. **KnitMesh Ltd., 36 Victoria Street, London, S.W.1.**

BCE 365 for further information

Controlled Humidity Independent of Air Temperature

A system recently introduced into the U.K. is based on the drying properties of kathene, a liquid absorbent containing lithium chloride. A unit employing this desiccant, the Kathabar, consists essentially of an air drying tower containing cooling coils, a kathene regenerator tower containing heating coils, and a kathene pumping unit and drainage tank situated beneath the towers. The kathene solution is pumped to nozzles above each of the two coils. About 85 per cent of the kathene flows over the humidity conditioning coil (cooling), where it absorbs moisture from the air, and the remaining 15 per cent flows over the regenerator coil (heating), where it gives up its moisture content to the scavenger air.

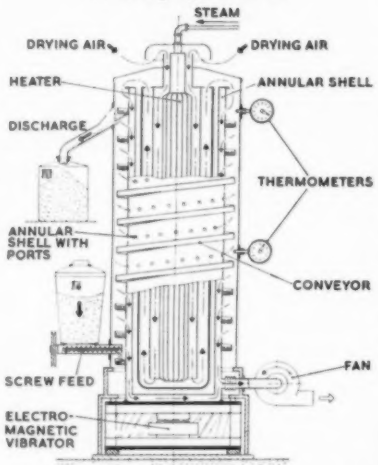


The lower the temperature of the kathene solution, the drier the air, and the humidity of the air is controlled by regulating the temperature of the kathene. Kathabar humidity conditioning is achieved independently of air temperature.

The unit is fully automatic and can operate up to five years before the kathene needs to be changed. The units find many applications, and it is claimed that they can remove 97 per cent of bacteria in the air. A range of standard units is available for 1350, 2500, 3500 and 5000 cfm, and they can also be made for any capacity. They are now available in the U.K. under licence from the International Engineering & Trading Society N.V., Holland. **Chemical Engineering Division, W. C. Holmes & Co., Turnbridge, Huddersfield.**

BCE 366 for further information

Vibratory Spiral Drier



The main advantages claimed for a drier which makes use of the vibratory-conveyor principle are freedom from particle disintegration, dustless operation, low power consumption, low space requirements, ease of control and the possibility of recovering solvents when solvent-moist solids are being dried. Moreover, the drying capacity of the equipment, known as the Xerotron, can be regulated by adjusting the rate of solids feed by varying the speed of conveying, by adjusting drying gas temperature and the quantity of drying gas drawn through the equipment.

The apparatus, which is particularly suitable for granular materials, consists of a spiral conveyor built around a heater, which uses either steam, electricity or heat transfer fluid as the source of heat, over which drying air or gas is passed. The gaseous drying medium, passing through a system of slots in the annular shell to which the spiral conveyor is attached, is caused to flow positively across the surface of the vibrating mass of solids. The feed is accomplished by means of a hopper and screw conveyor and the discharge is generally by chute from the discharge end of the conveyor into a suitable receptacle and circulation of the air or gas is by induced-draught fan. The material, in passing up the spiral, encounters warmer and dryer air as it proceeds to its exit, where it is under the influence of the greatest possible potential for drying.

Tailor-made units are offered and the manufacturing company is prepared to undertake tests on 5-kg samples on behalf of interested customers. **Hispano Suiza (Suisse) S.A., Geneva.**

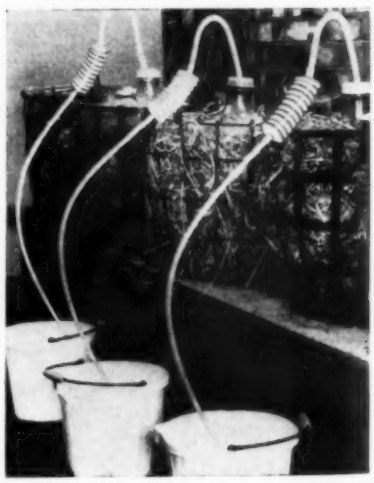
BCE 367 for further information

Siphon for Dangerous Liquids

An extremely simple siphon for the safe and economical transfer of liquids from one vessel to another will find applications in all industries using dangerous liquids.

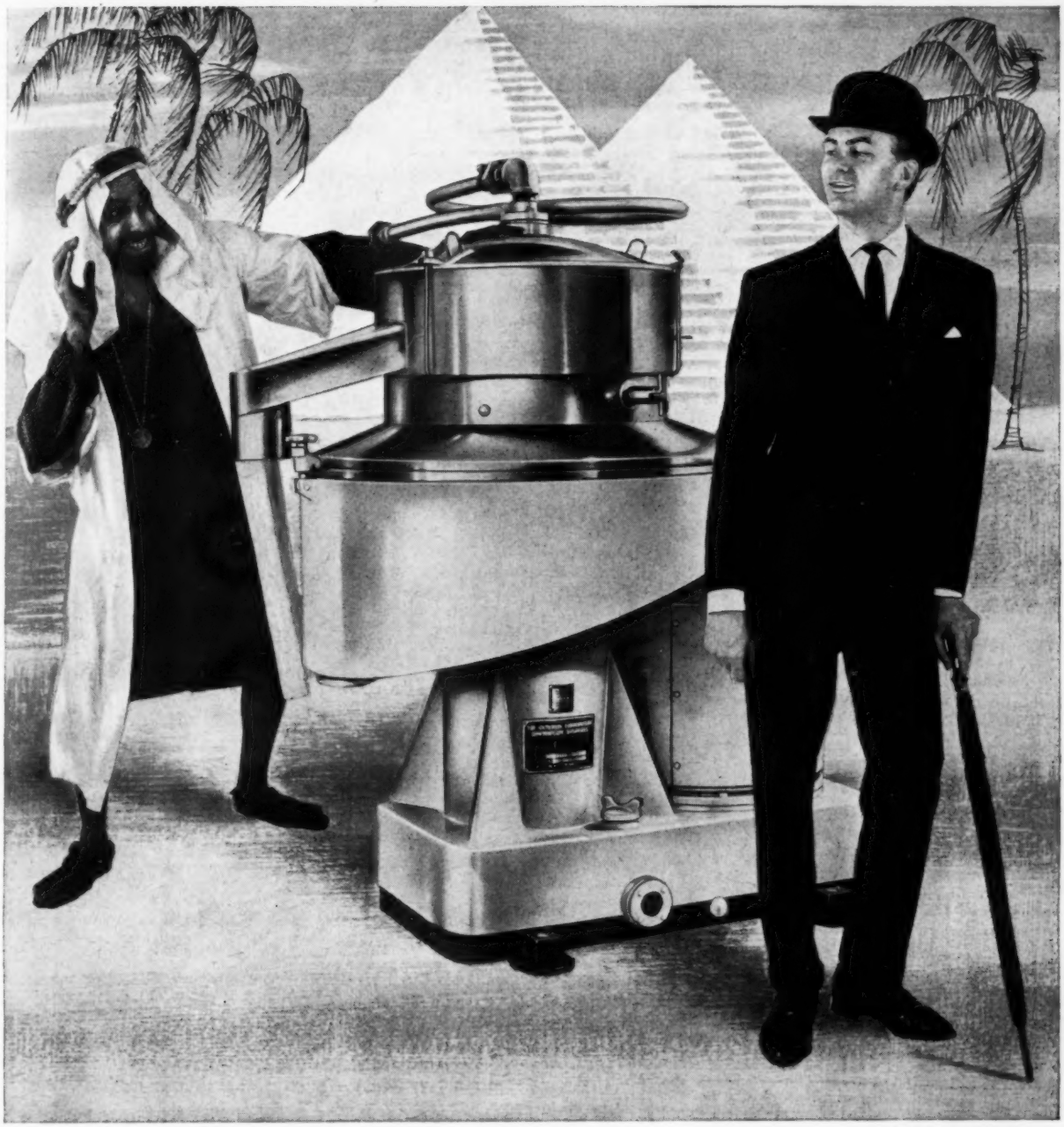
Manufactured from corrosion-resistant polyethylene, this siphon, the Dohm-Vorax, consists simply of a tube, with a tap at one end and a concertina-like bellows pump towards the other. In use, the tap is turned to the closed position, the bellows are compressed and the open end is inserted in the vessel from which the liquid is to be taken. The bellows pump is released and liquid is drawn into the tube. By opening the tap, the liquid is allowed to flow freely through by siphon-action, with the flow always readily under control at the tap.

It is claimed that in this way all liquids can be transferred with a minimum of danger to workers and without the mess and waste associated with tipping and pouring from one heavy vessel to another.



Two models are available, Model AA, bellows capacity ¼ pint, price 35s, and Model A AG, bellows capacity 3 pints, price 67s, from **Dohm Ltd, 167 Victoria Street, London, S.W.1.**

BCE 368 for further information



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P23A

PLANT EQUIPMENT NEWS

Mechanized Submerged-arc Squirt Welder

This equipment, the Idealarc ML-/, enables a welding operator to carry out both butt and fillet welding on plate thicknesses from as thin as 10 gauge or $\frac{1}{4}$ in. to the largest sections normally encountered in fabrication work. Welding speeds are about two to three times faster than those of normal hand welding and there is no need for the complicated handling equipment required of fully automatic processes.

Manufactured by the Lincoln Electric Co., of Cleveland, Ohio, U.S.A., this unit is now marketed in the U.K. **Armco Ltd., 76 Grosvenor Street, London, W.1.**

BCE 369 for further information

Drive Control

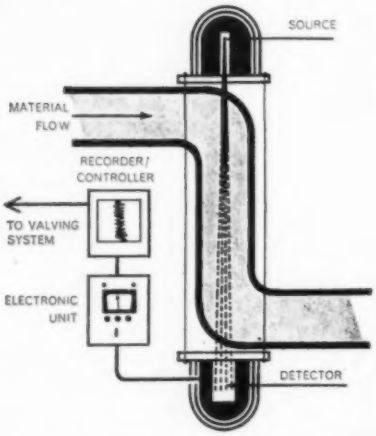
Drives which make use of semi-conductor control techniques throughout have been developed which are suitable for driving centrifuges and paper-making machinery where very close light limits are required; they are capable of giving a 20:1 speed variation with constant torque. From the speed represented by the lower limit of this range, control is possible down to zero, but in this case the torque is not constant. For the paper-making application the feedback feature of the equipment is capable of maintaining a no-load speed within 1 per cent of that at full load.

This equipment, now manufactured by Lancashire Dynamo Electronic Products Ltd., is available as a single package complete with integrally mounted motor generator and is available off the shelf in certain preferred ratings from 1-10 hp, while larger sizes to 100 hp can be supplied to special order. Similarly, a wide variety of control characteristics can be provided, the desired features being assembled into the unit from a range of off-the-shelf sub-assemblies and plug-in control units. This drive, known as the "Transidyne", is supplied complete with remote-control station equipped with push-button starting, reversing and finger-tip speed setting. **Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.**

BCE 370 for further information

Liquid/Slurry Density Gauges

The continuous measurement of the density of a solution or slurry directly in a process pipe without contacting the material and without moving parts can be achieved with the new Qualicon series of density gauges.* The new process systems for high sensitivity measurement and control of densities may be used, for example, for solids control of coating solutions in the paper industry; water content of fruit concentrate in the food industry; detection of pipeline interfaces in the petroleum industry; control of acid concentration in the chemical industry; and solids control of thickener underflow in the mining industry.



A cæsium-137 source in the measuring head produces gamma-rays which pass through the material at a rate that is inversely related to its density. These are detected by the Dynacell and converted into the measurement signal.

Measurements accurate to within 0·0001 specific gravity units are attainable. Gauges are designed for immediate integration into existing plant processes without disruption of production. **Nuclear-Chicago Corporation, 333 East Howard Avenue, Des Planes, Illinois, U.S.A.**

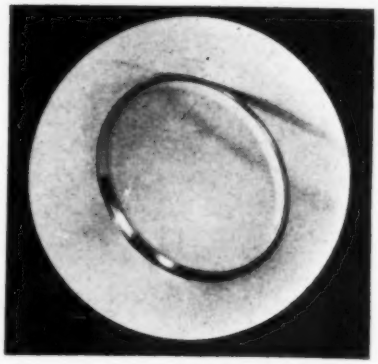
BCE 371 for further information

* A British firm, Saunders-Roe & Nuclear Enterprises Ltd., have also developed a method for the continuous measurement of liquid density using a radioactivity gauge. It was described in this journal recently. See Digest, *Brit. Chem. Eng.*, 1961, **6**, 1, 2.

Seal for High Temperatures and High Pressure

Designed to operate at temperatures from −65°F to 600°F and under pressures up to 10,000 psi, this new two-stage static seal has a high-yield-strength stainless-steel V-ring preceded by a Teflon seal.

The outer ring, made of high yield-strength Armco 17-4PH stainless steel, maintains the seal under extreme temperatures and pressures. The Teflon primary seal, permanently joined to the metal component, provides a "soft seat" for completely leak-tight sealing. The units are re-usable.



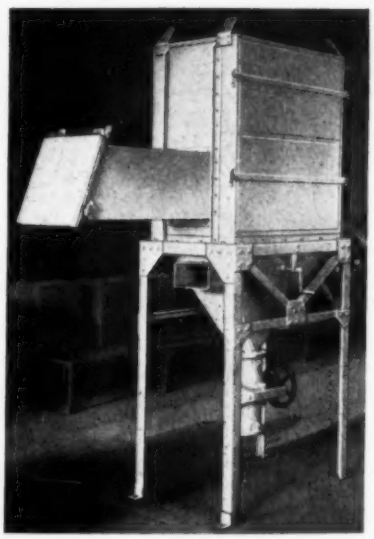
The seal is highly resistant to corrosion and compatible with nearly all fluids. The use of Teflon eliminates the need for cure dates, simplifying service and stock controls.

Similar rings are available with Viton "A" primary seal for use over the temperature range −70°F to +400°F. **Pall Corporation, 30 Sea Cliff Avenue, Glen Cove, N.Y., U.S.A.**

BCE 372 for further information

Dust Collector

The "Unimaster" dust collector is designed to handle "Dalapon"* which, in addition to posing a possible explosion hazard, tends to arch when in a repose position in the hopper. The inspection doors are therefore strengthened and firmly anchored, and an extended explosion-relief duct fitted. To overcome the arching properties a hand-operated

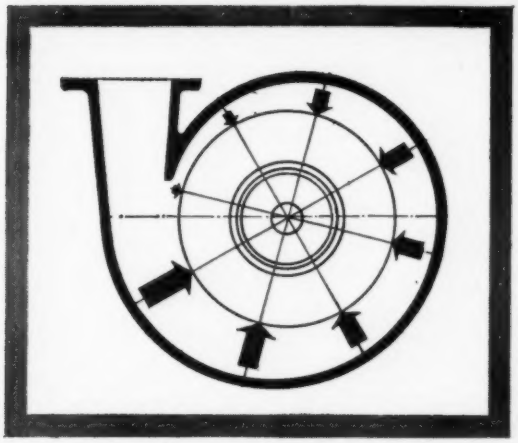


cranked lever is fitted in the top of the hopper, and the collected dust is discharged downwards back into the system through a 6-in. dia. rubber tube pinch valve. **Dallow Lambert Ltd., Thurmaston, Leicester.**

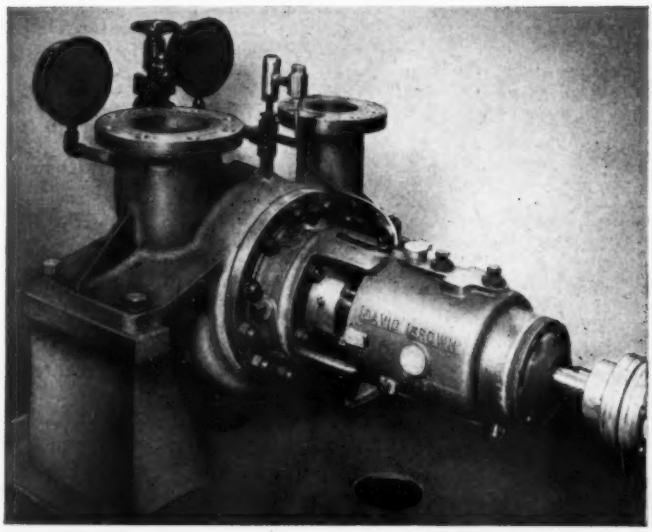
* "Dalapon" is an agricultural chemical manufactured by Lankro Chemicals Ltd.

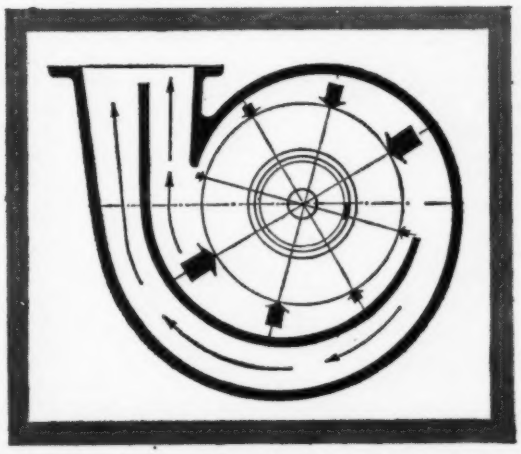
BCE 373 for further information

Why HYDRAULIC RADIAL BALANCE makes so much difference to the life of a centrifugal pump



See how the outdated single volute construction promotes uneven pressure around the periphery of the impeller, causing excessive bearing wear, excessive maintenance, excessive costs !





Double volute construction of David Brown 'Bingham' Pumps ensures equal pressures on opposite sides of impeller, giving hydraulic radial balance. Result—long life, infrequent maintenance.

'Bingham' double volute centrifugal pumps

—cast, machined, assembled, tested under one roof by

DAVID BROWN

100 YEARS 1860-1960

THE DAVID BROWN CORPORATION (SALES) LIMITED

PUMPING CORROSIVES?

The resources and experience of the David Brown metallurgical laboratories are at your disposal.

FOUNDRIES DIVISION, PENISTONE, NR. SHEFFIELD. Telephone Penistone 3311

OAI0660

PLANT EQUIPMENT NEWS

Handling Production Data

What is claimed to be the most advanced system for recording and writing complete production data from individual units in a process was recently introduced into this country.

In the equipment designed for this purpose (known as the "Productograph"), information is supplied via transducers which convert the information to an electrical signal, which is then fed to the "Productograph" control centre along wires. The control centre may deal with 20, 40, 60, 100 or 200 transducer sources of information, each source being a different unit, machine, process or other item requiring control.

The control centre consists of several units which indicate and record the quantity of product produced; the productive and idle times of plant units; the production cycles, etc., of each unit. Subsequent analysis of this information leads to improved planning, which results in increased productivity, through elimination of unnecessary idle time and bottlenecks.

Adrema Ltd., who acquired the marketing and assembly rights for Great Britain from Siemens-Halske, Germany, have installed a "Productograph" in their machine shop, where it can be seen in operation. **Adrema Ltd., Telford Way, London, W.3.**

BCE 374 for further information

Porous PTFE Filter Elements

Porous PTFE filter elements of varying pore size and shape can now be obtained as a result of a new method of manufacture. The filter elements, which apart from filtrations can be used as aerators, are resistant to all known chemicals, except molten alkali metals and some fluorine compounds. Free area is 78-80 per cent, density about 0.7 gm/cc, and tensile strength is 350 psi at room temperature. The pores are spherical and are connected by channels about 15 per cent of the pore diameter. Such a structure gives a high flow rate for a low pressure drop. PTFE softens at 327°C (620°F) and can be used at −200°C (−328°F).

Five grades of pore sizes are available, the coarser grades having the highest permeability. Wall thickness is $\frac{1}{16}$ in. to $\frac{1}{8}$ in. according to grade and shape, and a variety of shapes can be produced.

Q	R	T	W	Y	Grades
5	10	15	30	60	Pore size microns
2.5	10	20	40	80	Permeability (Darcies)
4.4	17.5	35	70	140	Flow rate (cc/sec)

1 Darcy = 10^{-8} cm²

The flow rates given above are based on water at 1 psi for a filter 1 sq in by 0.1 in. thick. **International Technical Developments Ltd., Willow Road, Poyle Estate, Colnbrook, Bucks.**

BCE 375 for further information

New Dual Zone Temperature Controller

A new mercury-in-steel, on-off temperature controller, which has independent circuits allowing control at any two points through one instrument, has been produced.

Each of the two controller circuits consists of alloy steel Bourdon tubes, capillaries and temperature-sensitive bulbs, operating mercury switches rated up to 30 amps at 230/250 A.C. The differential is fixed, but varies according to switching capacity.

Indicator lamps and bottom-entry electrical conduit are standard. Temperature ranges are available between −20°F and +1000°F (minimum coverage 100°F) and the equivalent °C.

The case is aluminium alloy and the standard capillaries 10 ft copper sheathed with mild-steel bulbs screwed ½ in. B.S.P. **British Rototherm Co. Ltd., Merton Abbey, London, S.W.19.**

BCE 376 for further information

Liquid-whistle Homogenizer

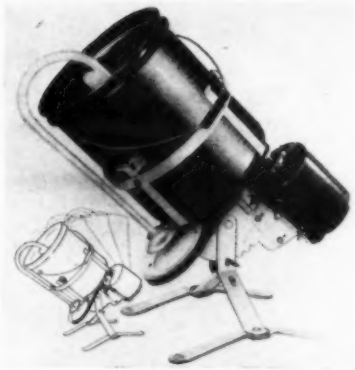
An ultrasonic homogenizing and dispersing unit based on the principle of the liquid whistle has been specially designed for the high-speed dispersion of powders in liquids.

The unit, the Dispersonic, consists of the vibrating element (18-22 kc/s) and an integral pumping unit driven by a direct-coupled 3-hp motor. Construction is all-stainless steel and it occupies only 5 sq ft of floor space.

The throughput for a machine of only 3 hp is approximately 5 gpm. There is neither aeration of the product, nor any heating effect, as sonic energy solely is used for dispersing. **Ultrasonics Ltd., Westgate, Otley, Yorkshire.**

BCE 377 for further information

Portable Mixer



This portable mixer will mix up to 70 lb in a 4½-gal pail at any one of four angles. It weighs 37 lb, occupies 2 sq ft and the drum turns at 50 rpm. It is suitable for mixing cement, mortar, plaster, compost, loam, concrete (which, it is claimed, it prepares in 30 sec). A special paddle permits mixing paints, adhesives, plastics, printing inks, and powder/water mixtures, etc. Known as the Kol mixer, it costs £21 19s 6d complete, with £2 2s 6d extra for paddles. **General Trade Equipment Ltd., 82-90 Seymour Place, London, W.1.**

BCE 378 for further information

Infra-red Spectrophotometer

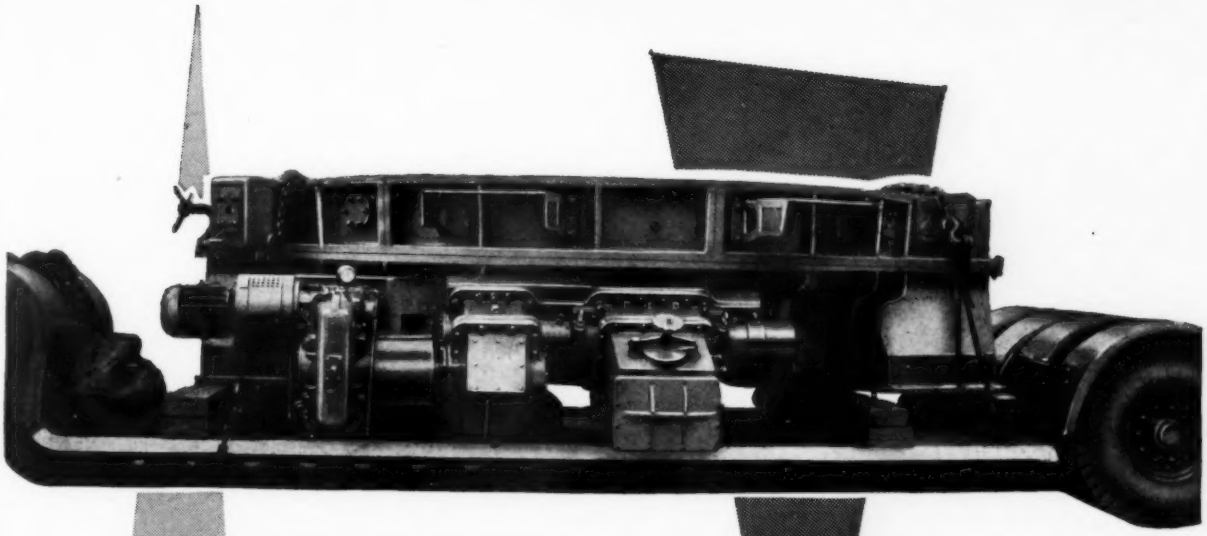
The model 137 Infracord spectrophotometer is a reliable low-cost instrument suitable for the rapid identification and measurement of organic chemicals. It is compact in design and simple to use, giving answers in minutes instead of hours. Infra-red spectra are widely used in the control of product purity and thus the spectrophotometer plays an important role through all the processing steps from raw material checks to analysis of the finished products. Also the instrument has many applications in research and teaching. Some useful accessories are available. It has an f/5 monochromator, 70° NaCl prism and a range of 2.5 to 15μ. **Perkin-Elmer Ltd., Beaconsfield, Bucks.**

BCE 379 for further information

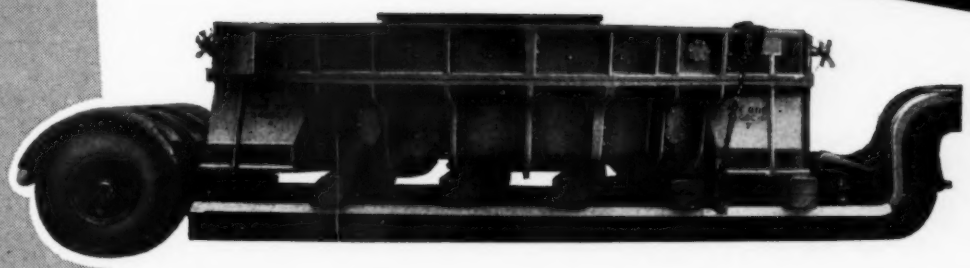
Dry Cooling Tower System

Enquiries for the equipment described under this head (BCE 9130) in the February, 1961, issue of this journal should be directed to **The English Electric Co.**, who are the sole licensees in the U.K., or **I. Bier & Son (Iron & Steel) Ltd.**, who are the sole agents of Messrs. Komplex for the Commonwealth.

BCE 319 for further information



Widnes Castings



Widnes Foundry and Engineering Co. Ltd. produces castings up to 30 tons. A recent contract, for Humphreys and Glasgow Ltd., is illustrated: a cast iron revolving base unit for a water gas generator, 13′ 10″ dia., 17′ 7″ overall length.

APPROVED BY LLOYD'S FOR CLASS 11 WELDING FOR PRESSURE VESSELS.

WIDNES FOUNDRY & ENGINEERING CO. LTD.

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W 53

PLANT EQUIPMENT NEWS

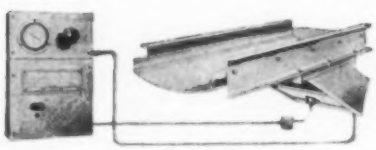
Vacuflex Large-bore Plastic Hose

This reinforced thermoplastic hose made of high-grade abrasion-resistant PVC and strengthened by high-tensile steel wire is now available in larger sizes. It can be obtained in any diameter between 4 and 12 in., and in lengths up to 15 ft. It is so flexible that it can be easily bent around a radius equal to its core diameter. This makes it ideal for ventilation and dust and fume extraction ducting. It is lighter and easier to install than metal ducting. It can be bent around obstacles without the need for elbows and bends. **Recon (Pipelines) Ltd., Albert Drive, Sheerwater, Woking, Surrey.**

BCE 380 for further information

New Vibrating Feeder

One of the novelties shown at the recent Liège International Fair was a mechanical vibrating feeder designed on the natural frequency principle, its main components consisting of an A.C. motor mounted directly between two banks of heavy-duty pneumatic springs. A small centrifugal force is generated by means of an offset weight fitted to the motor shaft and this force is amplified by the pneumatic springs in order to vibrate the trough. The adjustment of capacity is simple—one simply varies the amount of air pressure in the air cushions in order to change the amplitude of vibration. This can be done either manually or automatically.



Running costs are very low; thus when the feeder operates at natural frequency the pneumatic springs supply up to 90 per cent of the energy required. The equipment is available in a range of sizes and the equipment, known as the Locker Amplitrol, has exceptional capacity. It can also accommodate a greater head load than any other type of vibrating feeder of similar size.

The feeder can handle most granular materials at rates of up to 1500 tons per hour. **Locker Industries (Sales) Ltd., Warrington.**

BCE 381 for further information

EGO Proportioning Control Equipment

This electronic grading operator is designed for the control of rapid and accurate mixing of many types of materials. It operates on basic units of volume of the final mix, which can contain ten or more constituents in any proportion.

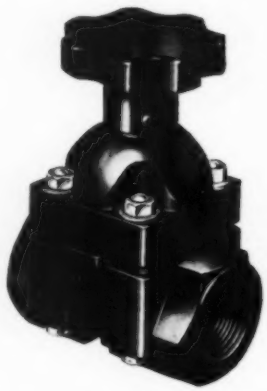
The components must be stored in fixed containers each with electrically controlled gravity discharge, and a conveyor system must link all the containers.

This equipment is claimed to be the only completely automatic grader of its type. **Dewhurst & Partners Ltd., Hounslow, Middlesex.**

BCE 382 for further information

HSB Saunders Valves

This new type of Saunders diaphragm valve is suitable for acid atmospheres in which the whole valve needs to resist corrosion. The body, bonnet and handwheel are made from high-styrene butadiene polymer, a material which is light in weight and has a chemical resistance similar to that of ebonite.



Sizes available are ½ in., ¾ in. and 1 in. at 80 psi and 70°C maximum temperature. **Saunders Valve Co. Ltd., 23 Palace Street, London, S.W.1.**

BCE 383 for further information

Continuous Flow Refractometers

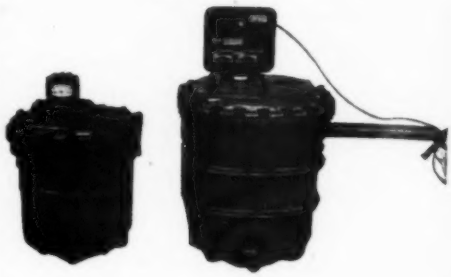
The principal feature of a range of industrial refractometers is the use of a null balance system which has the advantage of providing long periods of uninterrupted instrument operation. The following units are available:

A self-contained unit for temperate conditions, clean atmospheres and normal pressures (Type M.540). Another (Type M.541) in which the measuring unit is protected from dirt, vapours, etc. Its ancillary electronics are in a separate unit, which can be located away from the measuring head. Finally there is a bench-mounted model suitable for rapid batch working in test laboratories (Type M.550).

All three units compare the refractive index of a sample with that of a standard liquid. The fused glass and stainless-steel reference cells are immersed in a temperature-regulating bath. For better temperature control, a heat exchanger is available for stabilizing the temperature of the sample and reference liquids. The instruments are not suitable for liquids more turbid than "bitter lemon". **Hilger & Watts Ltd., 98 St Pancras Way, Camden Road, London, N.W.1.**

BCE 384 for further information

Ancillary Equipment for High-pressure Gas Meters



A base pressure index and a base volume index for use with high-pressure gas meters are now available. They enable the complete elimination of the complicated calculations hitherto associated with accurate measurement of gas at high pressures.

The base pressure index automatically compensates for the gas pressure by mechanically multiplying the volume of gas by the pressure factor and registers the amount of gas at base pressure which has passed through the meter. The base volume index performs an identical task but also compensates for temperature.

A supplementary volume and pressure gauge is available for use with both instruments. This gauge plots on a chart the time and pressure at which each thousand cubic feet of gas passes through the meter, thereby providing a permanent record for analysis and reference purposes. In the photograph, the meter on the left has a normal index and the one on the right is fitted with a base volume index. **Parkinson Cowan Ltd., Gas Meters Division, Terminal House, Grosvenor Gardens, London, S.W.1.**

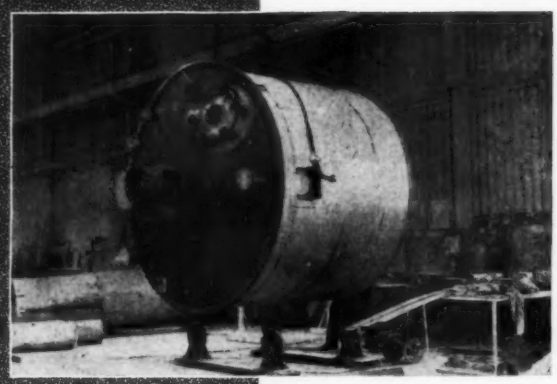
BCE 385 for further information

Thinwall-bellows Joints

Zallea expansion joints are used to absorb movement in a wide variety of piping applications, particularly in the oil and chemical industries. Both axial and lateral movements are accommodated with any pressure between vacuum and 1000 psi, and temperatures in the range −320°F to 1600°F. C. A. Parsons has signed a licence agreement with Zallea Bros. of the U.S.A. for the manufacture and sale of these joints in this country, the E.F.T.A. and the Commonwealth and are now able to accept enquiries for expansion joints suitable for normal bores of 3 in. to 48 in. for delivery after mid-1962. **C. A. Parsons & Co. Ltd., Heaton Works, Newcastle upon Tyne.**

BCE 386 for further information

LEONARD SMITH (ENGINEERS) LTD.



ANNOUNCE A DIVISION

Fabricating orders and enquiries are now being handled by our subsidiary, ASME Vessels Ltd.

The new works, now well-established, will undertake fabrication in Stainless Steel, Nickel, and Aluminium for customers and for its parent Company Leonard Smith (Engineers) Ltd.

The Chemical Engineering Service will continue to be given by Leonard Smith (Engineers) Ltd. as before.

Class 1 approval for Stainless Vessels

LEONARD SMITH (ENGINEERS) LTD.
ASME VESSELS LTD.
12 HIGH STREET · GILLINGHAM · KENT
Telephone : Gillingham 50220/1 *Telegrams : Eeless Gillingham, Kent*

PLANT EQUIPMENT NEWS

Small Valve with Rubber Muscle

A valve known as the Sala, which is now well-established as a means of controlling the flow of slurries, has recently become available in sizes of 1 in. and lower.

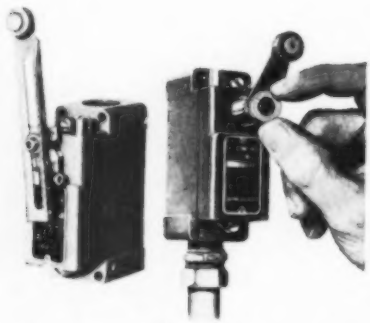
Its outer casing is of cast aluminium and closure is effected by hydraulic or pneumatic pressure on the rubber muscle, as in the standard valve. The inner liner of neoprene is, however, extended and recessed to fit over a standard steel pipe and to be secured with hose clips. Sizes are 1-in., ½-in. and ¼-in. bores and intermediate sizes can be supplied to order. **Neldco Processes Ltd., Crossway House, Bracknell, Berks.**

BCE 387 for further information

Oil-type Limit Switch

Two unique operating arms are available as additions to the "Square D" Class 9007 type AW limit switch range.

The first is an adjustable length roller arm (illustrated on the left), adjustable in length from 1 in. to 4 in. The use of this arm will eliminate wasteful setting-up modifications and conserve design labour.



The second addition is a roller arm infinitely adjustable through 360° (illustrated on the right). The arm can be adjusted to any angular position by rotating the knurled adjusting micrometer dial on the spindle of the arm. A graduated scale on the spindle is clearly marked in 20-degree graduations for easy setting of the arm position. One complete turn of the micrometer dial will move the arm through 20 degrees from one graduation mark to the next. A reference mark is located on the moving portion of the arm and the micrometer dial is provided with a position indicator. In consequence, accurate presetting and subsequent adjustment of the arm to any angular position is easily accomplished. Arms are available with a roller ⅝ in. dia. by ¼ in. wide and in various lengths from ⅝ in. to 3 in. long. **Square D Ltd., Cheney Manor, Swindon, Wilts.**

BCE 388 for further information

New Publications

Introducing Sturtepak Anodes is the title of leaflet No. 6003 issued by Sturtevant Engineering. The anodes, which have been designed to exploit the advantages of the latest zinc alloys using a newly developed solid backfill, can be used to protect service pipes and large pipelines; filling stations, depots and tank farms; and for the suppression of interference corrosion and the provision of combined earthing and cathodic protection. The leaflet gives technical details, and describes installation and services provided. **Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.4.**

BCE 389 for further information

Gelanol Data Sheet. This brochure provides details of Gelanol, a rust inhibitor for drawn bar, rod, etc., which consists of lanolin derivatives, gelling agents, a corrosion inhibitor and mineral lubricating oils. Summer and winter grades are available, though the latter grade is suitable for most purposes. **Croda Ltd., Cowick Hall, Snaith, Goole, Yorkshire.**

BCE 390 for further information

Chemical Consolidation in Civil Engineering Practice. This folder describes the process of chemical consolidation, which is a grouting injection process in which the air or water in the pores of a granular soil is partially, or wholly, replaced by chemical fluids which set after injection, thus increasing the strength, and reducing the permeability of the soil. **Soil Mechanics Ltd., 65 Old Church Street, London, S.W.3.**

BCE 391 for further information

Plant and Equipment. This 8-page, illustrated, multi-lingual publication lists in English, French, German and Spanish the various chemical, gas, petroleum and petrochemical plants which are supplied and erected by the **Power Gas Corporation Ltd., 15 Portland Place, London, W.1.**

BCE 392 for further information

Rock Mechanics. In this chart are tabulated, for easy reference, the measurement and observation techniques employed in the engineering of underground excavations, open excavations and foundations. Available from the newly formed company: **Rock Mechanics Ltd., 65 Old Church Street, London, S.W.3.**

BCE 393 for further information

Silicones for Foam Control. Three brochures describe the use of "Silicolapse"-type antifoam agents, and F110 and F111 fluids for foam prevention in dyebaths; sewage purification; tar distillation; gum and varnish manufacture; bottle-washing plants; papermaking, pharmaceutical, and other industries. **Imperial Chemical Industries Ltd., Nobel Division, Silicones Department, Stevenston, Ayrshire.**

BCE 394 for further information

Protective Treatment for Non-ferrous Metals. This folder provides information on a chemical polishing and protective treatment for copper, brass and bronze products with a powder of the protective chromate conversion coating type ("Lustre-on 70"). The powder is dissolved in water, and articles are dipped in the solution.

"Lustre-on 70" can be applied as a final finish or as a pretreatment prior to plating. **Tool Treatments (Chemicals) Ltd., Colliery Road, Birmingham Road, West Bromwich, Staffs.**

BCE 395 for further information

Molten Sulphur. Advice on the handling and storage of molten sulphur is contained in this 12-page booklet published by F. W. Berk & Co Ltd. The company pioneered long-distance transportation of molten sulphur and have storage facilities which ensure continuous deliveries. Molten sulphur is a purer uncontaminated product, free of dust, capable of being handled automatically by pumps, and requiring less storage space. Fire risk and corrosion losses are reduced and less heat is required to keep the molten sulphur ready for use. **F. W. Berk & Co. Ltd., Heavy Chemical Department, Stratford, London, E.15.**

BCE 396 for further information

The Nuclear Energy Industry in the U.K. This 67-page, well-illustrated book published by the U.K.A.E.A. provides general information on nuclear energy activities in the U.K., and the numerous companies which are associated with this activity.

The range covers power stations and reactors, chemical process plants and equipment, fuel elements, isotopes, research and training facilities in nuclear science offered by A.E.A., universities and colleges in the U.K. **United Kingdom Atomic Energy Authority, London, S.W.1.**

BCE 397 for further information

Automation and Process Control. This 8-page illustrated brochure describes the services provided by Automatic Control Engineering Ltd., in designing instrumentation systems and control laboratories, and assembling and installing systems in a variety of industries. **Automatic Control Engineering Ltd., Roxby Place, Seagrave Road, London, S.W.6.**

BCE 398 for further information

Nitrogen and Hydrogen Plants. This new 8-page brochure describes seven types of nitrogen plant and one hydrogen plant which are built by **The Incandescent Heat Co. Ltd., Gas Atmospheres Division, Smethwick.**

BCE 399 for further information

BCE 321 for further information

OXYGEN ANALYSIS

a new tool

The original Cambridge magnetic type oxygen analyser is now complemented by the filament type described below.

It is insensitive to CO_2 in the carrier gas and does not need to be level (an important advantage on board ship).

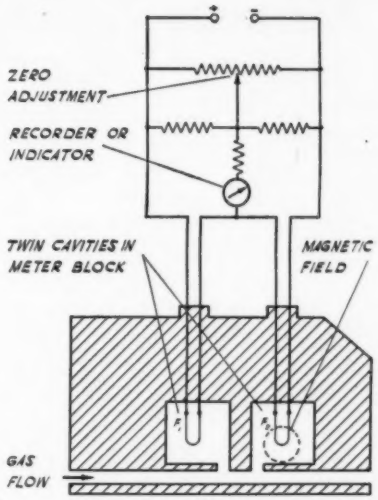
Whilst a major application will continue to be the measurement of excess air in furnace flues, many other industries will appreciate its qualities, which include high sensitivity and rapid response and, because of thermostatic control and pressure compensation, stable operating conditions.

It can be used with a galvanometric or electronic indicator and/or recorder.

The following is a brief description of the principle of operation:

The two filaments are heated by an electric current and form two arms of a Wheatstone bridge.

A magnetic field is directed across the cell containing filament F_2 in such a way that it is partly within the heated zone created by the filament and partly outside it. When a sample gas containing oxygen passes through the instrument, the oxygen is attracted into the magnetic field, the attraction being greater at the cool edge of the field owing to the higher paramagnetic susceptibility of the cool oxygen. The consequent pressure difference across the field induces a flow of gas which cools filament F_2 altering its resistance in relation to F_1. This causes an unbalance of the bridge, the amount of which is measured by an indicator or recorder calibrated directly in oxygen percentage.



Write for new List AR281. For future publications ask for Mailing Form AR/9/61

Cambridge OXYGEN ANALYSERS (Magnetic Types)

CAMBRIDGE INSTRUMENT COMPANY LTD., 13 GROSVENOR PLACE, LONDON, S.W.1 Tel: BELgravia 5066 Ext. 14

Corrosion problems solved

WITH THE FCT RESIN BONDED

GLASS FIBRE

PACKAGED WATER COOLING UNITS

* Efficient Cooling
* Low Maintenance Cost
* Splashless Operation
* Low Pumping Head
* Choice of Colour
* Less Ground Area
* Complete with Tank

IT'S AN F.C.T. PRODUCT WORTHY OF YOUR INVESTIGATION

Write for further details to Dept. B.C.E. 13

FILM COOLING TOWERS (1925) LTD

CHANCERY HOUSE, PARKSHOT, RICHMOND, SURREY. Tel. Richmond 6494 (5 lines) Grams: Aloof, Richmond, Surrey

BCE 322 for further information

World of Chemical Engineering

New Processes

Tokyo Government Laboratories report the development of a catalyst for ammonia synthesis having a life of 13,600 hours compared with 300-2000 hours of conventional catalysists. A ton of the new catalyst will produce 130,000 tons of ammonia compared with the 1000 tons currently obtained. A new process for the manufacture of nitric acid which eliminates the emission of the brown nitrogen peroxide fumes characteristic of conventional processes has been announced by the **Hercules Powder Co.** A solution of magnesium nitrate replaces the sulphuric acid, and the 60 per cent nitric acid obtained from ammonia oxidation is concentrated by extractive distillation to 99 per cent acid. A new Hungarian fertilizer process appeared at the Budapest Industrial Fair. Dolomite is used as a base material instead of limestone and offers important advantages both in manufacturing and in storing.

Domestic beryllium ores have been successfully concentrated by a flotation process using chemical reagents developed for the purpose, announced **Beryllium Resources Inc.**, of California. Topaz ore (primarily bertrandite) is used in the pilot plant, but the process is economical for other processes as well.

A group of Australian chemists working for the Department of Mines have developed a process for the recovery of scandium as scandium oxide from uranium residues.

New techniques for the settling and clarification of underground water in mines, involving the introduction of the inflow in the cleaning system from the bottom of the sump leading to the pumps and allowing it to flow the short width distance and not the length, have been developed in South Africa. The water is considerably slowed down, allowing it to drop its dirt load. The problem of finer matter in stable suspension is solved by allowing the cloudy water to rise through a bed of flocculated particles in a "V"-shaped trough. The finer suspended particles coagulate with the descending microscopic particles and leave the effluent as virtually clear water.

The Georgia-Pacific Corporation, who last year began production of wood-based cyanide and sulphate chemicals, are studying with **The Allied Chemical Corporation** the possibility of using their recently patented new processes for developing commercial production of other chemicals from wood.

After more than 12 years of research, **E. I. du Pont de Nemours & Co.** have developed a new high-temperature-resistant polyamide fibre known as HT-1. Among the many applications foreseen are filtration of hot gases and special duty belting. A pilot plant for its production will be constructed at Richmond, Virginia.

In their annual report for 1960 **Phillips Petroleum Co.** announce a number of interesting developments. They have evolved a new polypropylene process, now at the pilot plant stage; and a process for polymerization-grade isoprene. During 1960 they launched a novel, lower-cost version of their "Marlex" polyolefin process to make polymers used in monofilament rubber, etc.

A new group of synthetic organic acids produced from olefins, carbon monoxide and water by a process developed at the Shell laboratories in Amsterdam are being marketed under the trade name "Versatic". The pilot plant will be replaced by full commercial production shortly.

Monsanto Chemical Co. now manufacture 105 per cent phosphoric acid known as Phospholeum at their Addyston, Ohio, plant.

CIBA, who owns the **Toms River Chemical Corporation** complex in New Jersey, produce their own anthraquinone by a process based on continuous vapour-phase oxidation which is more efficient and produces higher yields than existing processes based on liquid-phase operation. There are three stages in this process: melting and vaporizing of anthracene; catalytic oxidation of anthracene to anthraquinone; and product recovery by selective sublimation of the crystals followed by vapour-phase filtration.

Conferences

oint A.S.M.E.-A.I.Ch.E. Heat Transfer Conference

A feature of the recently-concluded joint A.S.M.E. and A.I.Ch.E. conference on heat transfer was the strong representation from the United Kingdom. The conference itself covered almost every field of this extensive subject, many of which are of interest to chemical engineers. Some twenty papers were devoted to heat transfer in equipment, and a similar number to each of heat transfer at high-speed flow rates and the effect of vibrations and pulsating flow upon heat transfer. More than seventeen papers were given on subjects related to combined heat and mass transfer and to heat transfer in packed and fluidized beds. Other sections of the conference were concerned with free convection, internal and duct flow, heat conduction and thermo-electric effects, boiling and burn-out, condensation and two-phase flow.

In the heat transfer equipment sections papers from United Kingdom authors included "The Solution to the Dimensions of Corrugation-type Heat Exchangers" (R. J. V. SNELL); "Heat-transfer Coefficients in Town-gas Heated Equipment" (E. A. K. PATRICK and N. G. PATEL); "Calculation of Flue Gas Recirculation and Heat Transfer in Heaters using High-velocity Gas Burners" (W. E. FRANCIS and MISS H. E. ROUGHTON); "Heat Transfer During Evaporation of High-quality Water-steam Mixtures Flowing in Horizontal Tubes" (C. ROUNTHWAITE and M. CLOUSTON); "Tests on a Rotating Tube Heat Exchanger Having Controlled Fluid Flow" (R. F. PETTENDEN and A. D. RICHARDS); "Performance Coefficients for Cooler-condensers in the Gas Industry" (G. S. CRIBB); "The Fusion of Granular Solids" (T. K. ROSS); "Heat and Mass Transfer in Sublimation Drying of Foods" (J. C. FORREST, J. M. DAGLEISH and H. P. THOMPSON); "Heat Transfer and Pressure Drop Data on Cooling-tower Packings, and Model Studies of the Resistance of Natural-draught Towers to Air Flow" (H. J. LOWE and D. G. CHRISTIE). Also in this group was an important paper by A. L. LONDON and D. C. BRIGGS ("The Heat Transfer and Flow Friction Characteristics of Five Offset Rectangular and Six Plain Triangular Plate-fin Heat Transfer Surfaces") and a paper from Sweden, "Laboratory Test Results with a Family of Heating Elements for Ljungstrom Air Preheaters" (A. LYSHOLM, T. J. MCVEIGH and R. GUSTAFSSON).

In the section dealing with condensation, another paper from Sweden was given by G. SELIN ("Heat Transfer by Condensing Pure Vapours Outside Inclined Tubes"), and R. G. H. WATSON and others, from the U.K., gave a paper entitled "Dropwise Condensation of Steam". In addition, in this section, a paper on critical boiling in tubes was presented by V. E. DOROSHCHUK (U.S.S.R.), and there were also two Japanese papers, "Heat Transfer in Film Boiling to Sub-cooled Liquids" by F. TACHIBANA and S. FUKUI and "Boiling Heat Transfer from a Flat Surface Facing Downward" by S. ISHIGAI, K. INOUE, S. KIWAKI and T. INAI.

In the series devoted to heat transfer at high-speed flow rates, an important paper was given by PROF. D. B. SPALDING entitled "Heat Transfer to a Turbulent Steam from a Surface with a Step-wise Discontinuity in Wall Temperatures" and another U.K. paper (F. J. EDWARDS and N. SHERIFF) dealt with "The Heat Transfer and Friction Characteristics for Forced Convection Air Flow over a Particular Type of Rough Surface". From Russia in this section came a paper entitled "Use of Thermodynamic Similarity in Generalizing Experimental Data on Heat Transfer" by V. M. BORISHANSKY, I. I. NOVIKOV and S. S. KUTATELADZE. In addition to

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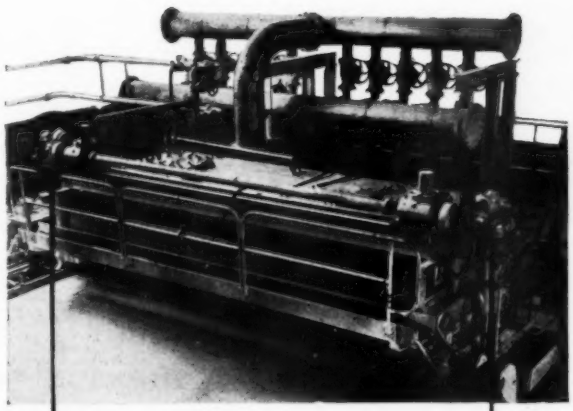

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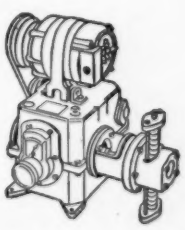

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these papers, a number of papers were given on the effect of vibrations and flow pulsations on heat-transfer rates. Thus, F. J. BAYLEY, *et al.*, presented a paper on the effect of flow pulsations on heat transfer by forced convection from a flat plate. In the internal and duct flow group, L. D. PALMER and L. L. SWANSON reported measurements of heat-transfer coefficients, friction factors and velocity profiles for air flowing parallel to closely spaced rods, and B. S. PETUKHOV, *et al.*, from the U.S.S.R., described an investigation of heat transfer to fluids flowing in pipes under supercritical conditions.

In this section, also worthy of mention are a paper on the effect of the ratio of eddy diffusivities for heat and momentum upon liquid metal heat-transfer coefficients, by T. MIZUSHINA and T. SASANO of Japan; "The Effect of a Right-angled Bend on Heat Transfer in a Pipe" by A. J. EDE; and "Turbulent Heat Transfer in Pseudoplastic Non-Newtonian Fluids" by R. M. CLAPP.

In the section dealing with packed and fluidized beds and mass transfer a Russian paper dealt with heat and mass transfer processes in the boundary layer at phase and chemical conversions, and another dealt with heat transfer in a fluidized bed (S. S. ZABRODSKY). R. M. G. MEEK discussed the measurement of heat-transfer coefficients in packed beds by the cyclic method and J. A. MURRAY and B. W. MARTIN presented a paper on the performance of thermal regenerators under sinusoidal flow conditions.

Cryogenic Engineering Conference

Another important event held in August was the Cryogenic Engineering Conference held at the University of Michigan, and the subjects of its various sessions included cryogenic problems of space simulation, the future of cryogenics, heat transfer phenomena, cryogenic properties, physical equilibria, equipment design, fluid transfer phenomena and mechanical properties and test procedures for materials used at cryogenic temperatures. In addition, a number of selected short papers were presented. A number of papers reflected the interest in space flight. In this group a paper by J. D. HAYGOOD, *et al.*, described a novel vacuum pumping device which employs the combined principles of cryopumping, trapping and diffusion pumping, which is able to attain an ultimate vacuum exceeding 10^{-9} mm Hg.

In the group of papers dealing with equipment, T. J. WEBSTER and J. ROBB (B.O.C.) discussed factors affecting the design of no-loss high-pressure liquid-gas storage tanks. WEBSTER drew attention to the importance of such factors as stratification, materials of construction, insulant selection, ullage volume and distribution of heat-inleakage. It was shown that most tank designs are a compromise between mechanical practicability and thermal considerations. In this same group of papers, M. D. BLOOMER and R. F. SWEETMAN (General Electric) described a monitor for low-temperature storage vessels, the particular condition to be avoided being the plugging of vessel vents, containing, for example, liquid hydrogen or liquid helium, by frozen air. The instrument described is a thermal conductivity gas analyser operating in an unbalanced bridge, and it is fail-safe.

In the series on fluid transfer phenomena the gas requirement of the pressurized transfer of liquid hydrogen was dealt with by D. F. GLUCK and J. F. KLINE. They show that for static tank discharge the gas requirements are fixed mainly by gas-wall heat transfer, gas-phase enthalpy change and the specific enthalpy of the inlet gas. The paper presented a method of predicting the gas requirements within ± 7 per cent of the actual quantities.

In the section dealing with refrigeration systems for applications below 25°K, C. TREPP, of Sulzer Bros. Ltd., gave details of the performance and construction of radial reaction turbines equipped with oil bearings allowing a maximum rpm of 120,000. This expander was used in the 2 m hydrogen bubble chamber for CERN. An Axial flow liquid hydrogen pump described by M. C. HUPPERT and S. V. GUNN can handle 10,600 gpm at 50,000 ft developed head when running at 34,000 rpm; efficiencies in excess of 80 per cent and very low NPSH values have been obtained.

Among heat transfer papers, several are worthy of mention here; for example, C. W. COWLEY *et al.* described a method for improving heat transfer from cryogenic fluids to thermally conductive solids. The method consists of coating the solid with an insulator of resistance sufficient to adjust the temperature difference between the coated solid and the cryogenic liquid to a value where greater heat transfer will take place. Other papers dealt with heat transfer to cryogenic hydrogen at supercritical pressures; W. R. THOMPSON and E. L. GEERY found that two minimum values occur for the heat-transfer coefficient. Another paper by D. E. DRAYER and K. D. TIMMERHAUS described an investigation into the individual boiling and condensing heat-transfer coefficients for hydrogen. This work covered a temperature-difference range of 0.38-6.06°F and a heat flux range of 23-978 Btu/hr sq ft. The values obtained are about 50 per cent greater than those predicted by a combination of the Forster-Zuber and Nusselt theories.

Among other recent important conferences was yet another devoted to heat transfer, held in Paris in late June, and one which took place a few weeks earlier in Prague, on fluidization.

French Heat Transfer Conference

This was sponsored by the Institut Français des Combustibles et de l'Energie, in conjunction with la Société Français des Thermiciens, under the presidency of PROFESSOR M. VERON.

The six-day programme of "les Journées Internationales de la Transmission de la Chaleur" attracted 500 delegates from 15 countries, and a total of 90 papers were presented (by 107 authors) on various aspects of heat transmission.

In the section on conduction, PROF. H. CORDIER talked of "Thermal Resistances of Contact", and HUETZ, LAVIGNE and VAUTREY presented "A Study of Thermal Resistances of Contact between Liquid Metals".

Among the papers on forced convection with no change of state, PROF. F. SCHULTZ-GRUNOW discussed "Turbulent Heat Transmission in *Stratified* Flow"; PROFS. C. BORY, H. CORDIER and M. MOUTON presented one on "Forced Heat Convection in Annular Spaces"; and DR. BAUER discussed "Heat Transmission in a Tube Bundle Normal to a Fluid".

The two papers on forced convection followed by chemical changes were by PROF. D. B. SPALDING on "Heat Transfer within Gases in Chemical Reaction", and by DR. M. P. VALENTIN on "Convection with Combustion: (1) on a Surface, and (2) in a Fluid Phase".

Four papers were presented on natural convection; five on convection in rarefied gases, at high velocities and high temperatures; and three on vaporization, boiling and condensation.

Papers on radiation included "Experimental Data on Radiation from Fuel/Oxygen Flames" by M. R. KISSEL; "Radiation from Very Hot Gases, Plasmas and Shock Waves" by M. H. DE L'ESTOILE; and "Selective Radiation of Refractories at High Temperatures" by M. R. ALEGRE.

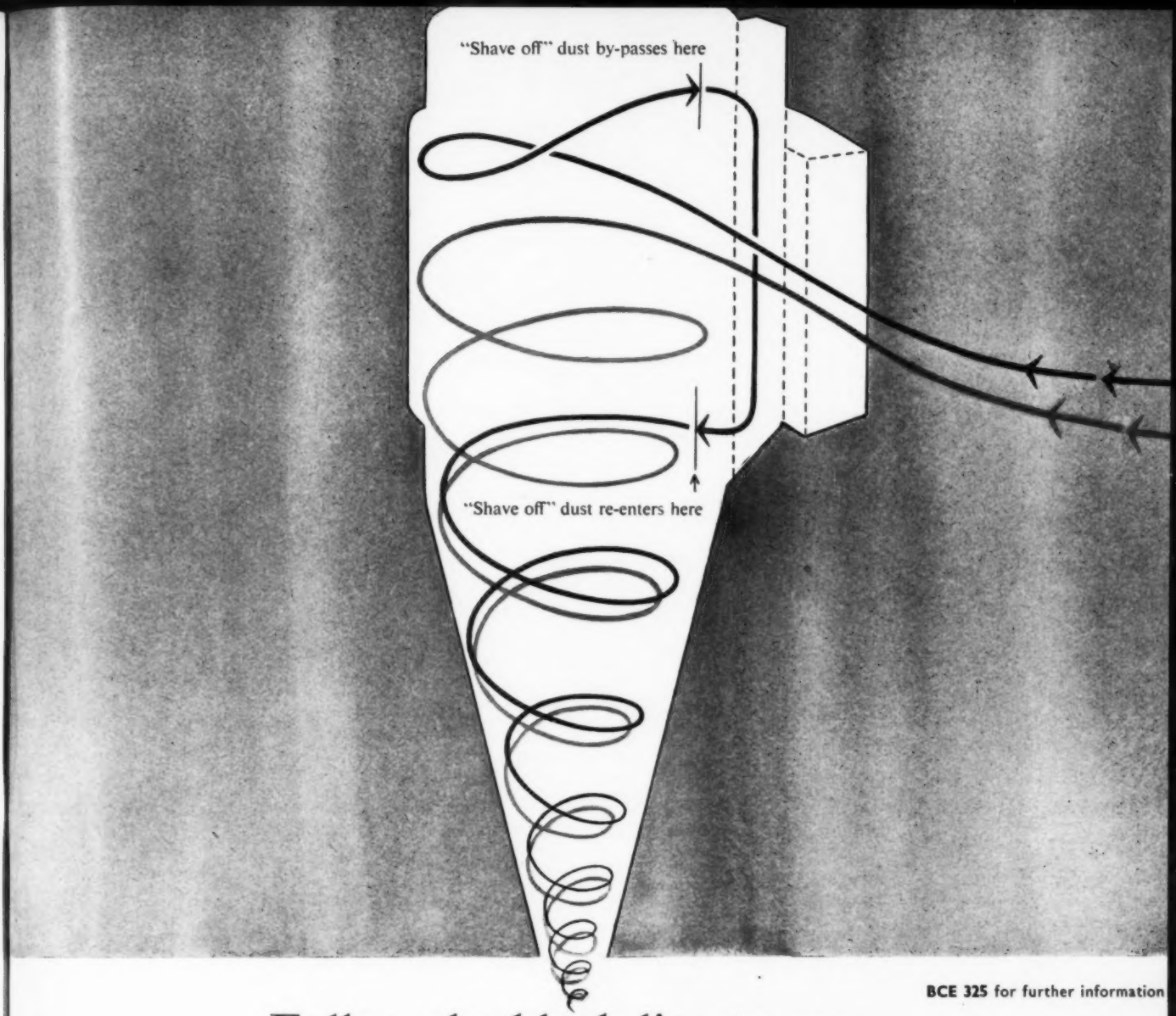
Of the numerous papers on heat exchangers, we would mention the "Comparison of Heat Exchangers Heated by Hot Water and Steam" by PROF. D. MALIC; the "Determination of Heat Losses to Atmosphere" by PROF. D. V. VELICKOVIC; and the "Use of Electronic Calculators to Solve Problems of Heat Transmission" by J. J. BOEHM and M. G. RABEK. In the same section were papers describing "Compact and Miniature Exchangers", by M. CONDAMIN, and "Liquid Metal Heat Exchangers", by M. ROBIN.

Finally, we would mention three papers dealing with heat exchanger materials of construction. They were on "Metallic Heat Exchangers for High Temperatures" by PROF. A. SCHACK; on "Refractory Products Employed in Thermal Exchangers" by M. MONTAGNIER; and on "Graphite Heat Exchangers" by M. DAHAN.

The complete proceedings, including the discussions, will be published in two volumes which can be ordered from the Institute Français des Combustibles et de l'Energie, 3 rue Henri-Heine, Paris-14e.

Personalities

Among the appointments announced during the month was that of **Mr. Godfrey Winters**, who is to be Manager of the Heat Exchange Division of Wellington Tube Works Ltd. Other appointments include **Mr. Roger Lawson**, who is to be Assistant Chief Engineer of Boots Pure Drug Co. Ltd.; **Mr. G. E. Timms**, to be Chief Engineer of the Silvertown factory of BTR Industries Ltd.; **Mr. Maurice Ruddick**, who will succeed **Mr. B. H. Oldfield** as Engineering Manager of Laporte Chemicals Ltd.; and **Mr. M. J. B. Hodgson** as Midlands Area Manager of Rhodes, Brydon & Youatt Ltd., manufacturers of centrifugal pumps. Also, Humphreys & Glasgow Ltd., of London, announce that **Mr. Roy Withers**, the Chief Engineer, and **Mr. Derek Lennon**, who is responsible for all overseas plant, are both to join the Board of Directors.



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Company News

Agents in Australia

Par-Tool Filters Ltd., of Luton, Beds., have appointed **Rusden, Birrell & Co. Pty. Ltd.** of Melbourne as exclusive agents for the distribution of Par-Tool filterplant in the Commonwealth of Australia. Their address is 120 Johnston Street, Fitzroy, N.6, Melbourne, Victoria.

It is also announced that the Coal Preparation and Mining Division of **Simon-Carves Ltd.** is being transferred to Carlisle as from 31 December, 1961. This move is to concentrate in one place the company's activities in coal preparation and mining work.

Expansion at Farnborough

A new headquarters, new research and production facilities and ancillary buildings for **The Solartron Electronic Group** were officially opened at Farnborough, Hants., by the RT. HON. REGINALD MAUDLING, M.P., President of the Board of Trade, on 17 July. Instruments, specialized equipment and various machines and systems were demonstrated and exhibited. These included oscilloscopes, analogue computers, business machines, data handling equipment, radar simulators, teaching machines, transducers and an X-ray fluorescent spectrometer.* Also demonstrated were some of the wide range of digital instruments for development, research and control-room purposes.

*This was described in Plant Equipment News. See *Brit. Chem. Eng.*, 1961, **6**, 8, 582.

New Plants in Brief

Expansion in Petrochemicals

Plans for the construction of an aromatic chemicals plant at Dinslaken, West Germany, have been announced by the **Standard Oil Co.** of California, and **The British Petroleum Co.** It will be operated by **Deutsche BP und California** using feedstocks from the adjoining BP Ruhr Refinery. Capacity will be 14,000 tons of high-purity paraxylene per annum. Another aromatics plant in Europe is one for Esso near the Rotterdam Refinery. To be completed in 1963, it will produce 220,000 tpa of benzene, toluene and xylene from petroleum. Also from Germany it is announced that the crude throughput capacity of **BP Benzin und Petroleum's** Hamburg Refinery is to be increased from 1.95 to 2.3 million tpa.

A new plant and other developments are announced by **BP Australia.** A £A300,000 lubricants blending plant is to be built near Sydney, and a new tanker berth is being constructed at the company's Berry's Bay installation. Also a completely new bulk oil installation is to be built at Eden, N.S.W.

Another refinery increasing its capacity is the one at Suez, U.A.R. The Italian firm **Compania Technica Industriale Petrolio** is to double the capacity of the refinery for the U.A.R. Government.

The Scientific Design Co. Inc., of New York, is to design and build Sweden's first direct air oxidation ethylene oxide plant for **Mo och Domsjo Aktiebolag.** It will be built at Stenungsund. News of more money to be spent on new plants, manufacturing facilities and laboratory testing equipment comes from the **Universal Oil Products Co.**, of Illinois, and its subsidiaries, who are to invest $6½ million.

Fabrication Facilities

The Kestner Evaporator & Engineering Co. Ltd. have recently opened their new foundry at Greenhithe—the first stage of the complete move of their works from New Cross to Greenhithe. The other shops will be transferred over the next six months. The new foundry is making castings of "Tantiron" acid-resisting silicon iron, and lead alloy-resisting castings. The new 21,000 sq ft Engineering Laboratory of the **British Welding Research Association**, opened at Abingdon in July, can tackle any industrial welding problem. **Whessoe Ltd.**, of Darlington, now have three operating divisions: for heavy equipment; light products; and engineering services.

In Germany **QVF Glastechnik GmbH**, a subsidiary of the British firm Q.V.F. Ltd., are building a new 41,000 sq ft factory at Wiesbaden-Schierstein; **G & E Engineering Ltd.** have undertaken a new expansion plan and can now handle much larger contracts for chemical plant, including items up to a weight of 3 tons.

Plastics and Fibres

I.C.I. Ltd is to establish a factory to manufacture "Perspex" acrylic sheet, "Diakon" moulding powder and methyl methacrylate at a 300-acre site in Rotterdam. This follows the announcement in February that I.C.I. intend to expand their interests in Europe.

"Building a Complex of Chemical Plants for Toms River Chemical Corporation" is the title of a booklet just published by the **M. W. Kellogg Co.** It describes the products produced at the plant which include liquid and solid Araldite epoxy resins and a wide variety of azo and vat dyes. **Chemstrand Corporation** plans to treble nylon yarn capacity at their Greenwood, South Carolina, plant.

Nitrogen and Fertilizers

A number of fertilizer plants in various overseas countries are to be built. The Indian Government has granted a licence for one to be built near the Caltex Refinery at Visagapatnam. It will cost $55 million, and will produce 350,000 tons of ammonium phosphate and 55,000 tons of urea annually. France is to provide NF70 million to finance a fertilizer plant at Da Nang, Vietnam. Production of urea and calcium carbonate will be undertaken. Another is to be in Portugal, where the **M. W. Kellogg Co.**, of New York, is undertaking the construction for **Uniao Fabril do Azoto**, of Lisbon. Plants to manufacture ammonia, nitric acid, urea, ammonium nitrate and ammonium carbonate will be installed. Finally, a fertilizer factory costing eventually £2 million will be built at Sasolburg, South Africa.

From Hungary there is news that the nitrogen works of Pet have begun the manufacture of high-purity argon gas suitable for welding. Some of the output is available for export.

Organic Chemicals

Badisch Anilin & Soda Fabrik A.G. (BASF) report that their large new plant for making phthalic anhydride will shortly come on-stream. **Morrison-Krudsen International Constructors** are to build a $38 million urea plant at Palembang for the Indonesian Government. The raw material will be natural gas from adjacent deposits.

New detergent alkylate plant.

Australia's first detergent alkylate plant came into production recently at the Geelong refinery of **The Shell Company of Australia Ltd.** Its 7000 tpa output will save £A½ million annually in foreign exchange, as all previous supplies had to be imported.

There are two announcements in the field of rubber manufacturing. A dehydrogenation plant to produce butadiene from normal butane or from mixtures of butane and butenes is being built near Rio de Janeiro, Brazil. The process is one licensed from **Houdry-Brazilian Co.** Also, **Dunlop Japan** are to expand further their Kobe and Nagoya factories, investing £5 million over the next two years.

Among other miscellaneous new plants, the following were announced. **Cyanamid International** are to build a second major antibiotics plant in Europe, at Catania in Sicily. It will produce the main broad spectrum antibiotics, Ledermycin, Achromycin and Aureomycin, as well as various others. The Calcutta firm **Sirajuddin & Co.** is to manufacture 5000 tons of silicon a year to be used in a ferrosilicon plant. From Sweden comes news of a new plant at **Svenska Kolsyrefabriken, Stockholm**, to make liquid and solid carbon dioxide by burning oil in steam boilers, The CO_2 in the flue gas is to be absorbed, purified, desorbed, compressed and condensed by machinery operated by the steam produced. Cooling is provided by an ammonia plant whose compressor is combined with the CO_2 compressor.

Acalor (1948) Ltd. have been contracted to apply their high-corrosion-resistant coating to the internal surface of a mile of steel pipeline of varying diameter at a new power station in the Midlands.